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Portland Cement Plant Inspection Guide

PEDCo-Environmental, Inc.
Cincinnati, OH

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The inspection guide describes the procedures that an inspector should follow before, during, and after conducting an inspection of a portland cement plant. The specific areas addressed are: 1) review of agency files prior to plant inspection, 2) procedures for entering the plant and conducting the preinspection interview, 3) information to be obtained from the plant exterior, 4) safety precautions, and 5) equipment needed to conduct an inspection. The guide describes each of the processes and sources of atmospheric emissions: feed preparation, clinker production, clinker cooling, finish grinding, and final product storage, packaging, and loading. Means for controlling atmospheric emissions are detailed along with specific descriptions of ESP's, fabric filters, cyclone separators, gravel bed filters, and containment and dust suppression practices. Also described are proper plant operating conditions, emission problems due to malfunctions and upsets, and startup and shutdown problems. After all information has been gathered, example emission calculations are provided to assist in determining the compliance of a plant.

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for

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DISCLAIMER

This report was furnished to the U.S. Environmental Protection Agency (EPA) by PEDCo Environmental, Inc., in fulfillment of Contract No. 68-01-6310, Task No. 35. The contents are as received from the contractor. The opinions, findings, and conclusions expressed are those of the authors and not necessarily those of the U.S. Environmental Protection Agency. Mention of company, process, or product name is not to be considered as an endorsement by the U.S. Environmental Protection Agency.

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SECTION 1

INTRODUCTION

1.1 PURPOSE AND SCOPE

This guide has been prepared to assist state and local regulatory personnel in the inspection of portland cement plants to determine whether they are in compliance with atmospheric emission regulations. Unless otherwise indicated, atmospheric emissions shall refer to total suspended particulate matter and visible emissions. When plants are suspected of being out of compliance, the guide will assist in determining reasons for violation, which should help the plant to locate problem areas. Offering specific process-related recommendations should be avoided, however, so that neither the agency nor the inspector personally can be held responsible for problems that could arise from following these recommendations.

This guide describes each of the processes associated with the manufacture of portland cement, the types of equipment used to control emissions from the processes, and associated operating and maintenance problems, and it provides procedures for inspecting the various processes to determine compliance. Because each jurisdiction has its own specific emission requirements, regulations other than the Federal New Source Performance Standards (NSPS) for Portland Cement Plants (Appendix A) have not been included in this guide. The inspector must become familiar with the regulations appropriate to the plant and specific sources prior to an inspection.

1.2 INDUSTRY OVERVIEW

The primary process in portland cement manufacturing is the calcining or sintering of carefully ground and mixed raw materials in an inclined rotary kiln fired by fossil fuel. The raw materials are clay, sand, iron ore, limestone shale, feldspar, etc., which contain calcium carbonate, silica, alumina, ferric oxide, etc. Five types of portland cement are manufactured in the United States. Each type differs in the composition of the raw materials and the production methods.

- Type I is used for general concrete construction when the special properties of the other four types are not required.
- Type II is used in general concrete construction exposed to moderate sulfate action or where moderate heat of hydration is required.
- Type III is used when high early strength is required.
- Type IV is used when a low heat of hydration is required.
- Type V is used when high sulfate resistance is required.

Chemical reactions that occur during calcining result in the formation of a clinker. Pulverizing these clinkers with gypsum yields a powder called portland cement. Mixed with water, portland cement forms a slowly hardening paste; when sand and gravel are added to the mixture, it becomes concrete.[1] Approximately 1.6 tons of raw materials are required to produce 1 ton of cement. On the average, about 35 percent (0.6 ton) of raw material weight is removed as carbon dioxide and water.[2]

In 1980, a total of 89.6 million tons of portland cement were produced by 156 plants in the United States.[3] The States of California, Pennsylvania, Michigan, New York, and Texas accounted for 43 percent of this production; Puerto Rico and 34 other states produced the remaining 57 percent.[3] Appendix B lists portland cement manufacturing plants in the United States according to ownership.

SECTION 2

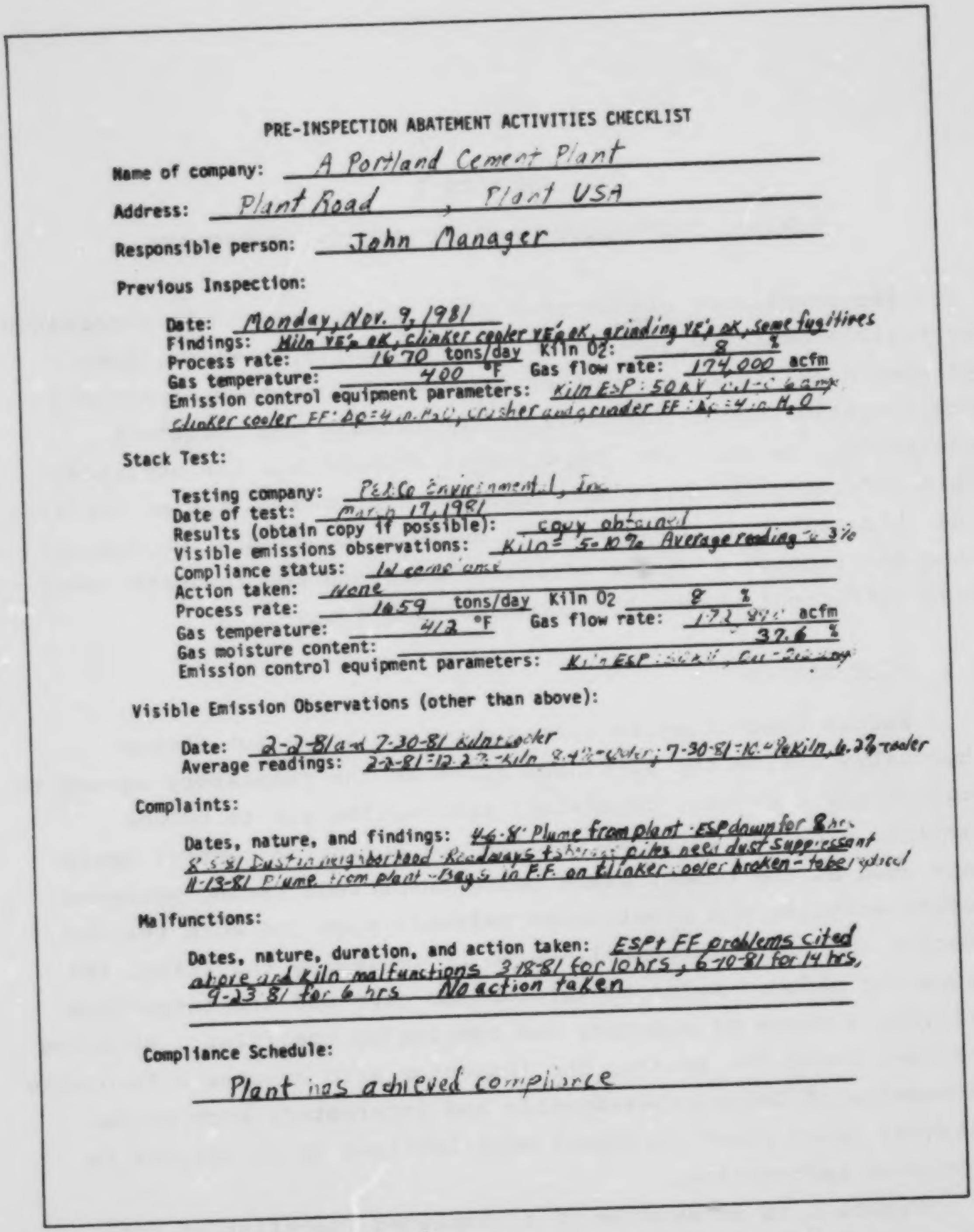
GENERAL PREPARATORY AND INSPECTION PROCEDURES

The compliance status of a plant sometimes can be determined by visible emission observations. Frequently, however, compliance determination requires detailed information concerning the operation and maintenance of the process and abatement equipment. Because the inspector is responsible for obtaining this information, this guide presents a procedure for accomplishing this task. In some cases, a definite conclusion on compliance may require a source emission test, and the inspector must have sufficient reason to recommend such a test.

2.1 FILE REVIEW

Before conducting an inspection, the inspector should thoroughly review the pertinent files at the regulatory agency to acquire the necessary regulatory information and to become familiar with the types of process and pollution control equipment used at the cement plant being inspected. Being prepared before entering the plant saves valuable time for both the inspector and plant personnel. Also by reviewing the files, the inspector becomes aware of information gaps and the inspection provides a means of updating and completing the files. By being informed about the source, the inspector also creates a favorable impression of being knowledgeable and interested; such an impression makes plant personnel more inclined to be helpful in providing information.

Figure 1 is an example of a completed checklist of specific information concerning previous abatement activities that the inspector should obtain from the files. Process and control



PRE-INSPECTION ABATEMENT ACTIVITIES CHECKLIST

Name of company: A Portland Cement Plant

Address: Plant Road, Plant USA

Responsible person: John Manager

Previous Inspection:

Date: Monday, Nov. 9, 1981
Findings: Kiln VE's ok, clinker cooler VE's ok, grinding VE's ok, some fugitives
Process rate: 1670 tons/day Kiln O_2: 8 %
Gas temperature: 400 °F Gas flow rate: 174,000 acfm
Emission control equipment parameters: Kiln ESP: 50 kV, [illegible] amps
clinker cooler FF: Δp=4 in. H_2O, crusher and grinder FF: Δp=4 in. H_2O

Stack Test:

Testing company: PEDCo Environmental, Inc.
Date of test: March 17, 1981
Results (obtain copy if possible): copy obtained
Visible emissions observations: Kiln = 5-10% Average reading = 3%
Compliance status: In compliance
Action taken: None
Process rate: 1659 tons/day Kiln O_2 8 %
Gas temperature: 412 °F Gas flow rate: 172,8[illegible] acfm
Gas moisture content: 32.6 %
Emission control equipment parameters: Kiln ESP: [illegible]

Visible Emission Observations (other than above):

Date: 2-2-81 and 7-30-81 kiln + cooler
Average readings: 2-2-81 = 12.2% - kiln 8.4% - cooler; 7-30-81 = 10.4% kiln, 6.2% cooler

Complaints:

Dates, nature, and findings: 4-6-81 Plume from plant - ESP down for 8 hrs.
8-5-81 Dust in neighborhood - Roadways + storage piles need dust suppressant
11-13-81 Plume from plant - Bags in F.F. on clinker cooler broken - to be replaced

Malfunctions:

Dates, nature, duration, and action taken: ESP + FF problems cited above and kiln malfunctions 3-18-81 for 10 hrs, 6-10-81 for 14 hrs, 9-23-81 for 6 hrs No action taken

Compliance Schedule:

Plant has achieved compliance

Figure 1. Sample form for information about previous abatement activities.

equipment information (described in later sections) also should be obtained at this time and recorded as seen in Figures 2 and 3. These checklists can be duplicated and used to obtain information during the inspection. Appendix C includes blank forms for this purpose. The comparison of past information, particularly data recorded during stack testing and other inspections, with information obtained during the current inspection can be helpful. The previous information should indicate a normal range of operating conditions for the process and abatement equipment, so that deviations from these are readily apparent. For example, excess visible emissions in conjunction with a lower than previously recorded pressure drop across a fabric filter would indicate broken or missing bags.

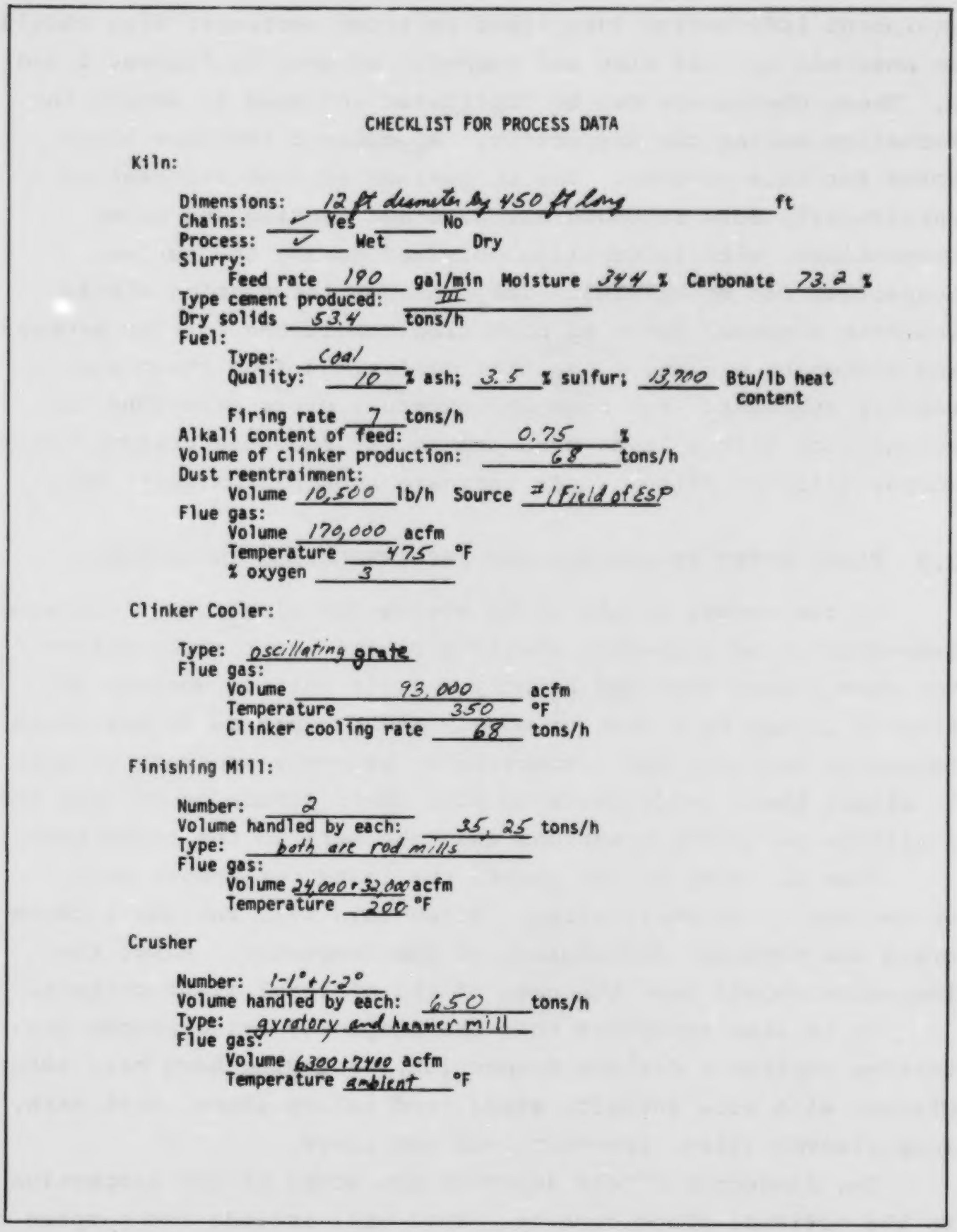
2.2 PLANT ENTRY PROCEDURES AND PRE-INSPECTION INTERVIEW

If the agency policy is to advise the plant of an upcoming inspection, the inspector should give the plant ample notice. For some plants that may be only a day's notice, whereas for others, it may be a week or more. Advance notice to key plant personnel can help the inspection to progress smoothly because it allows these individuals to plan their schedules so they are available to answer questions and take part in the inspection.

When arriving at the plant, the inspector should have proper agency identification. Often this will include a photograph and physical description of the inspector. Also, the inspector should have the name of the official plant contact.

It is also important that the inspector bring proper protective equipment for the inspection, including hard hat, safety glasses with side shields, steel-toed safety shoes, dust mask, a long-sleeved-shirt, trousers, and ear plugs.

The inspector should describe the scope of the inspection to the official plant contact. This will include the purpose of the inspection, a listing of the processes to be observed, and the approximate duration of the inspection.



CHECKLIST FOR PROCESS DATA

Kiln:

Dimensions: 12 ft diameter by 450 ft long ft
Chains: ✓ Yes ___ No
Process: ✓ Wet ___ Dry
Slurry:
Feed rate 190 gal/min Moisture 344 % Carbonate 73.2 %
Type cement produced: III
Dry solids 53.4 tons/h
Fuel:
Type: Coal
Quality: 10 % ash; 3.5 % sulfur; 13,700 Btu/lb heat content
Firing rate 7 tons/h
Alkali content of feed: 0.75 %
Volume of clinker production: 68 tons/h
Dust reentrainment:
Volume 10,500 lb/h Source #1 Field of ESP
Flue gas:
Volume 170,000 acfm
Temperature 475 °F
% oxygen 3

Clinker Cooler:

Type: oscillating grate
Flue gas:
Volume 93,000 acfm
Temperature 350 °F
Clinker cooling rate 68 tons/h

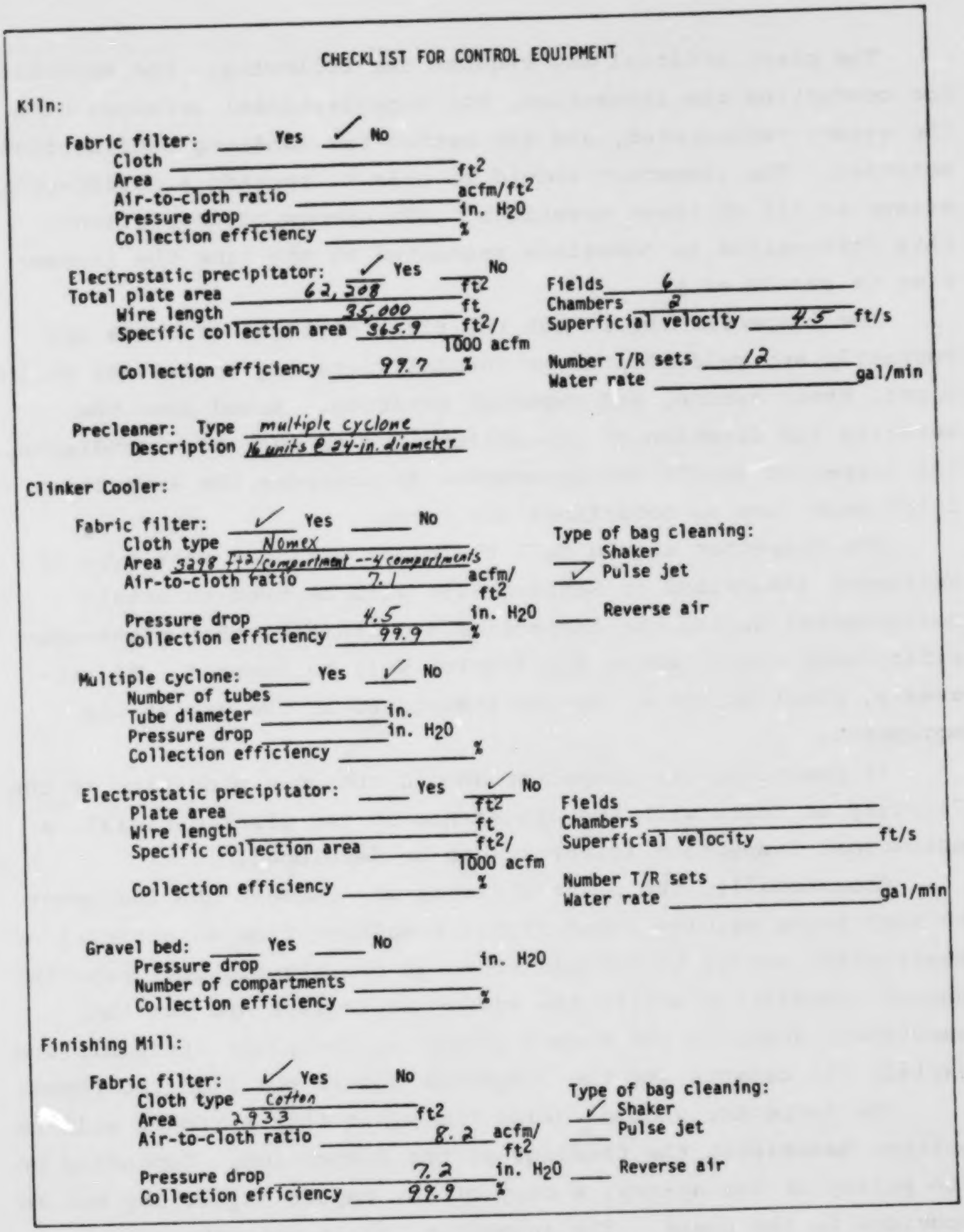
Finishing Mill:

Number: 2
Volume handled by each: 35, 25 tons/h
Type: both are rod mills
Flue gas:
Volume 24,000 + 32,000 acfm
Temperature 200 °F

Crusher

Number: 1-1° + 1-2°
Volume handled by each: 650 tons/h
Type: gyratory and hammer mill
Flue gas:
Volume 6300 + 7400 acfm
Temperature ambient °F

Figure 2. Sample form for information on process.



CHECKLIST FOR CONTROL EQUIPMENT

Kiln:

Fabric filter: ____ Yes [✓ No]
Cloth ____ ft^2
Area ____ acfm/ft^2
Air-to-cloth ratio ____ in. H_2O
Pressure drop ____ %
Collection efficiency ____

Electrostatic precipitator: [✓ Yes] ____ No
Total plate area 62,308 ft^2
Wire length 35,000 ft
Specific collection area 365.9 ft^2/1000 acfm
Collection efficiency 99.7 %
Fields 6
Chambers 2
Superficial velocity 4.5 ft/s
Number T/R sets 12
Water rate ____ gal/min

Precleaner: Type multiple cyclone
Description 16 units @ 24-in. diameter

Clinker Cooler:

Fabric filter: [✓ Yes] ____ No
Cloth type Nomex
Area 3298 ft2/compartment --4 compartments
Air-to-cloth ratio 7.1 acfm/ft^2
Pressure drop 4.5 in. H_2O
Collection efficiency 99.9 %

Type of bag cleaning:
____ Shaker
[✓ Pulse jet]
____ Reverse air

Multiple cyclone: ____ Yes [✓ No]
Number of tubes ____
Tube diameter ____ in.
Pressure drop ____ in. H_2O
Collection efficiency ____ %

Electrostatic precipitator: ____ Yes [✓ No]
Plate area ____ ft^2
Wire length ____ ft
Specific collection area ____ ft^2/1000 acfm
Collection efficiency ____ %
Fields ____
Chambers ____
Superficial velocity ____ ft/s
Number T/R sets ____
Water rate ____ gal/min

Gravel bed: ____ Yes ____ No
Pressure drop ____ in. H_2O
Number of compartments ____
Collection efficiency ____ %

Finishing Mill:

Fabric filter: [✓ Yes] ____ No
Cloth type Cotton
Area 2933 ft^2
Air-to-cloth ratio 8.2 acfm/ft^2
Pressure drop 7.2 in. H_2O
Collection efficiency 99.9 %

Type of bag cleaning:
[✓ Shaker]
____ Pulse jet
____ Reverse air

Figure 3. Sample form for information on control equipment.

The plant official may request the following: the authority for conducting the inspection, the organizational arrangement of the agency represented, and the method for handling confidential material. The inspector should be able to provide a satisfactory answer to all of these questions. (In announced inspections, this information is sometimes requested at the time the inspection is scheduled.)

The inspector should ask the plant official if there are currently any malfunctions or unusual operating conditions at the plant, their nature, and expected duration. Based upon the severity and duration of any malfunction or operating condition, the inspector should decide whether to postpone the inspection until such time as conditions are normal.

The inspector should tell the plant official what type of equipment (described in Section 2.5) will be used to obtain measurements during the inspection and indicate that plant-specific Union rules (where applicable) will be honored. If necessary, plant personnel can be instructed in the use of the equipment.

If possible, the inspector should obtain a plot plan of the facility so that, with the assistance of the plant official, a methodical inspection itinerary can be developed.

Occasionally, the plant official may request the inspector to sign forms waiving legal rights resulting from an accident or restricting access to certain areas of the plant. The inspector should immediately notify the agency supervisor and let the supervisor describe the agency policy to the plant officials and explain the reasons why the inspector should not sign the forms.

The inspector should advise the plant that a report will be written describing the findings of the inspection. Depending on the policy of the agency, a copy of the report may or may not be provided to the plant. The inspector should not make any comments concerning compliance status during the inspection.

If refused entry to the plant either when scheduling an inspection or during an unannounced inspection, the inspector should obtain a reason and the name of the person authorizing the refusal. No attempt should be made to identify the legal ramifications of the refusal. The inspector should simply notify the regulatory agency supervisor so that appropriate action can be taken.

2.3 EXTERIOR PLANT OBSERVATIONS

Before entering plant property or while moving from one process operation to another, the inspector can gain considerable information by viewing the exterior of the plant. Sources of fugitive dust which should be observed are raw material storage piles, heavy equipment movement on plant property, and transfer points for the material being moved from one process to the next. The inspector should also note the weather conditions (especially precipitation and windspeed) during and prior to the inspection. Evidence of excessive cement dust in the area surrounding the plant may indicate an emission problem. The inspector should look for dust accumulation on parked automobiles, houses, sidewalks, etc. Some dust in the area is natural because of the materials and processes involved. Odors resulting from the combustion of fossil fuels and raw materials may also be detected in the area of the kiln and should be noted if excessive.

These activities also provide an opportunity to observe the general housekeeping practices of the plant and give the inspector an overall picture of the plant layout for comparison with information obtained from the files. The inspector also can get an idea of the level of activity by observing the raw material and product loading operations, plant traffic, and equipment in operation.

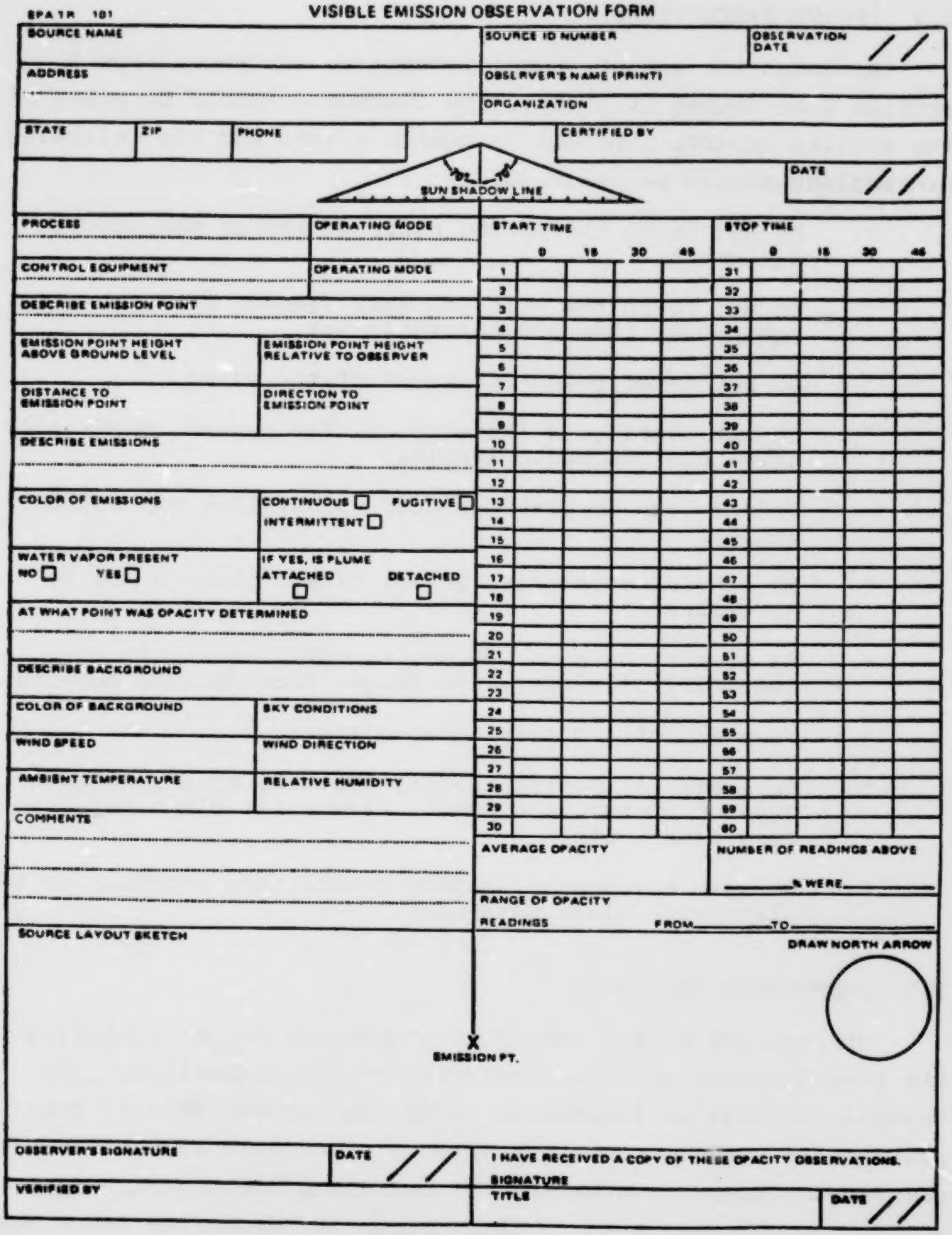
While off plant property, the inspector can normally use a camera to photograph excessive visible emissions or fugitive dust; however, some state laws prohibit the use of a camera without the prior permission of the plant. Data regarding any photographs taken (e.g., date, time of day, weather conditions, position relative to the source) must be recorded immediately. In all cases, permission to take photographs within must be obtained from plant officials.

Visible emission observations are important in determining the operating conditions of processes and associated control equipment. When observing opacity from stacks, the inspector should follow the procedures of Federal EPA Method 9 (Appendix D). Windspeed, sky condition, and other weather data are important because the reading may be challenged in court. Also important is a diagram identifying the particular source being read (e.g., the Nordberg hammermill for secondary crushing) and the observer's position in relation to the sun and the source. A sample visible emission observation form is shown in Figure 4.

The inspector should record opacity readings on the observation form for a specified duration, depending upon the local requirements. Although the regulation may specify a plume opacity below a certain average for say a 6-minute period, the inspector may want to take the reading for a longer period, say 30 minutes, and look for a 6-minute period that exceeds the limit.

Opacity readings are usually obtained most easily before entering the plant for the inspection or after leaving plant property. The inspector should compare the recorded opacities for a source with values obtained by the plant's continuous emission monitoring equipment (if available) for that source during the same time period. The frequency of calibration of these instruments should also be checked.

If the agency's policy is to provide the plant with a copy of the opacity readings, the plant official receiving the copy should sign and date the original.



EPA 1R 101

VISIBLE EMISSION OBSERVATION FORM

SOURCE NAME

SOURCE ID NUMBER

OBSERVATION DATE / /

ADDRESS

OBSERVER'S NAME (PRINT)

ORGANIZATION

STATE

ZIP

PHONE

CERTIFIED BY

DATE / /

SUN SHADOW LINE

PROCESS

OPERATING MODE

CONTROL EQUIPMENT

OPERATING MODE

DESCRIBE EMISSION POINT

EMISSION POINT HEIGHT ABOVE GROUND LEVEL

EMISSION POINT HEIGHT RELATIVE TO OBSERVER

DISTANCE TO EMISSION POINT

DIRECTION TO EMISSION POINT

DESCRIBE EMISSIONS

COLOR OF EMISSIONS

CONTINUOUS ☐ FUGITIVE ☐

INTERMITTENT ☐

WATER VAPOR PRESENT

NO ☐ YES ☐

IF YES, IS PLUME

ATTACHED ☐ DETACHED ☐

AT WHAT POINT WAS OPACITY DETERMINED

DESCRIBE BACKGROUND

COLOR OF BACKGROUND

SKY CONDITIONS

WIND SPEED

WIND DIRECTION

AMBIENT TEMPERATURE

RELATIVE HUMIDITY

COMMENTS

START TIME	0	15	30	45	STOP TIME	0	15	30	45
1					31				
2					32				
3					33				
4					34				
5					35				
6					36				
7					37				
8					38				
9					39				
10					40				
11					41				
12					42				
13					43				
14					44				
15					45				
16					46				
17					47				
18					48				
19					49				
20					50				
21					51				
22					52				
23					53				
24					54				
25					55				
26					56				
27					57				
28					58				
29					59				
30					60				

AVERAGE OPACITY

NUMBER OF READINGS ABOVE

_______% WERE_______

RANGE OF OPACITY

READINGS FROM_______TO_______

SOURCE LAYOUT SKETCH

DRAW NORTH ARROW

X

EMISSION PT.

OBSERVER'S SIGNATURE

DATE / /

I HAVE RECEIVED A COPY OF THESE OPACITY OBSERVATIONS.

SIGNATURE

VERIFIED BY

TITLE

DATE / /

Figure 4. Sample visible emission evaluation form.

2.4 SAFETY PRECAUTIONS

Although the use of proper protective equipment should provide some degree of safety, the inspector should be aware of the routine hazards inherent in cement plants and the following precautions should be observed:

- Do not touch the moving parts of any of the process equipment.
- Do not touch the kiln, clinker cooler, or associated equipment; they are extremely hot.
- Do not enter roped-off areas of the plant.
- Do not start up a ladder until the person immediately ahead has reached a landing.
- Do not lean on platform guardrails; they may not be secure.
- Be mindful of footing at all times; there could be obstacles.
- Be alert; there may be moving vehicles in the area, temporary platforms, and danger from falling objects.
- Be aware of and obey warning signs.
- Be aware of specific safety features governing each type of control equipment; always let plant personnel open doors, etc.
- Discuss any special safety precautions peculiar to this plant with plant personnel.

2.5 INSPECTION EQUIPMENT

The equipment used during an inspection varies according to the time allotted and the complexity of the inspection. For example, a detailed inspection involving several days at the plant could require the following: a pitot tube to measure the gas stream flows, a manometer for measuring the pressure drop across control equipment, a thermometer for measuring stack gas temperatures, a tachometer for measuring fan speed, an ammeter for measuring fan motor current, an oxygen meter for concentration of the kiln gases, and a flashlight for observing unlighted areas inside the control equipment. For a less detailed and shorter inspection, the inspector may only need a camera, a compass, and the proper protective equipment. Readings obtained from plant instruments (e.g., oxygen monitors on the kiln, thermocouples indicating temperatures of stack gases) should be recorded, however.

If permitted on plant property, a camera provides a useful tool, not only to illustrate excessive opacity levels, but also to describe problems arising from corrosion, poor housekeeping, missing bags or motors for the control equipment, proximity of sources to each other, etc. Immediately after taking a photograph, the inspector should write descriptions of the situation represented in each photograph and the time, date, weather conditions, and directional information.

A compass is useful in determining directions of sources relative to each other, to the sun, and to the inspector.

The volume of heavy equipment and raw material movement makes portland cement plants dusty and noisy by nature. Use of the proper protective equipment is important for the safety of the inspector. A dust mask and safety glasses with side shields are required in the dusty environment. A long-sleeved shirt and trousers provide some protection against hot materials. Steel-toed shoes and a hard hat are required to protect against overhead hazards and heavy objects. Ear plugs are required to prevent hearing damage in high noise areas such as crushing and grinding operations. Neckties, ribbons, and finger rings should not be worn during the inspection.

SECTION 3

PROCESS DESCRIPTION AND SOURCES OF ATMOSPHERIC EMISSIONS

Offsite processes that contribute to air pollution in the portland cement industry are the quarrying of raw materials and the transport of those materials to the plant site. Manufacturing plant sources of air pollution are the crushing, grinding, mixing, and blending of raw materials; clinker production; clinker cooling operations; finish grinding of the clinker with gypsum; and storage, packaging, and loadout of the finished product. Although this guide concerns itself only with the processes at the manufacturing site, it should be emphasized that quarrying contributes a significant amount of atmospheric emissions.

3.1 SIMPLIFIED CHEMICAL AND PHYSICAL DESCRIPTION OF CEMENT FORMATION

The basic raw materials in portland cement manufacturing contain calcium carbonate, silicon oxide, alumina, and ferric oxides with minor amounts of sulfate, alkali, and carbonaceous materials. Chemically combined water and carbonaceous materials are removed because of the heat from the feed end of the kiln. As the temperature is increased, the alkali materials are volatilized and removed with the kiln gases. Limestone (calcium carbonate) dissociates to calcium oxide and carbon dioxide under atmospheric pressure at 1650°F, and alumina begins to decompose at about 1800°F. (These initial reactions begin before any liquid has formed. Liquid formation takes place at the surface and extends into the grains only by the slow process of diffusion.) Interaction between CaO and SiO_2 begins to occur in a liquid phase when the material reaches about 2000°F. The reaction speeds up at 2500°F, and dicalcium silicate forms in the presence of liquid, which first appears at about 2350°F. The interaction of dicalcium silicate with additional CaO to form tricalcium silicate (which is essential for the formation of portland cement) is slow, even at higher temperatures, but the presence of alumina and ferric oxide considerably increases the rate of formation. If the temperature fails to exceed 2500°F, only small amounts of tricalcium silicate are formed. In this case (referred to as dusting) the cement is valueless.[1]

3.2 FEED PREPARATION

Upon receipt from the quarry, the raw materials are crushed, screened, and ground to the appropriate size for mixing and blending before they are charged to the kiln. As Figure 5 shows, crushing sometimes takes place in two or three stages. Crushing, screening, and grinding operations may be vented to the atmosphere, and all are potential sources of particulate emissions. The emission rate depends on the kind of raw material and its moisture content, characteristics of the crusher, the kind of control equipment, and its operation and condition.

3.2.1 Crushing and Screening

Crushing reduces the size of rock obtained from the quarry. Crushing equipment typically consists of primary and secondary crushers, but sometimes tertiary crushers also are needed. Primary crushing reduces the quarry rock (often as large as 4 to 5 feet in diameter) to 6 to 10 inches in diameter by use of jaw, gyratory, and roll crushers. The type of crusher used depends on the hardness, lamination, and size of rock.

Figure 6 presents schematics and illustrations of the different types of crushers. Jaw crushers consist of two steel jaws that accept material to be crushed. As the swing jaw moves

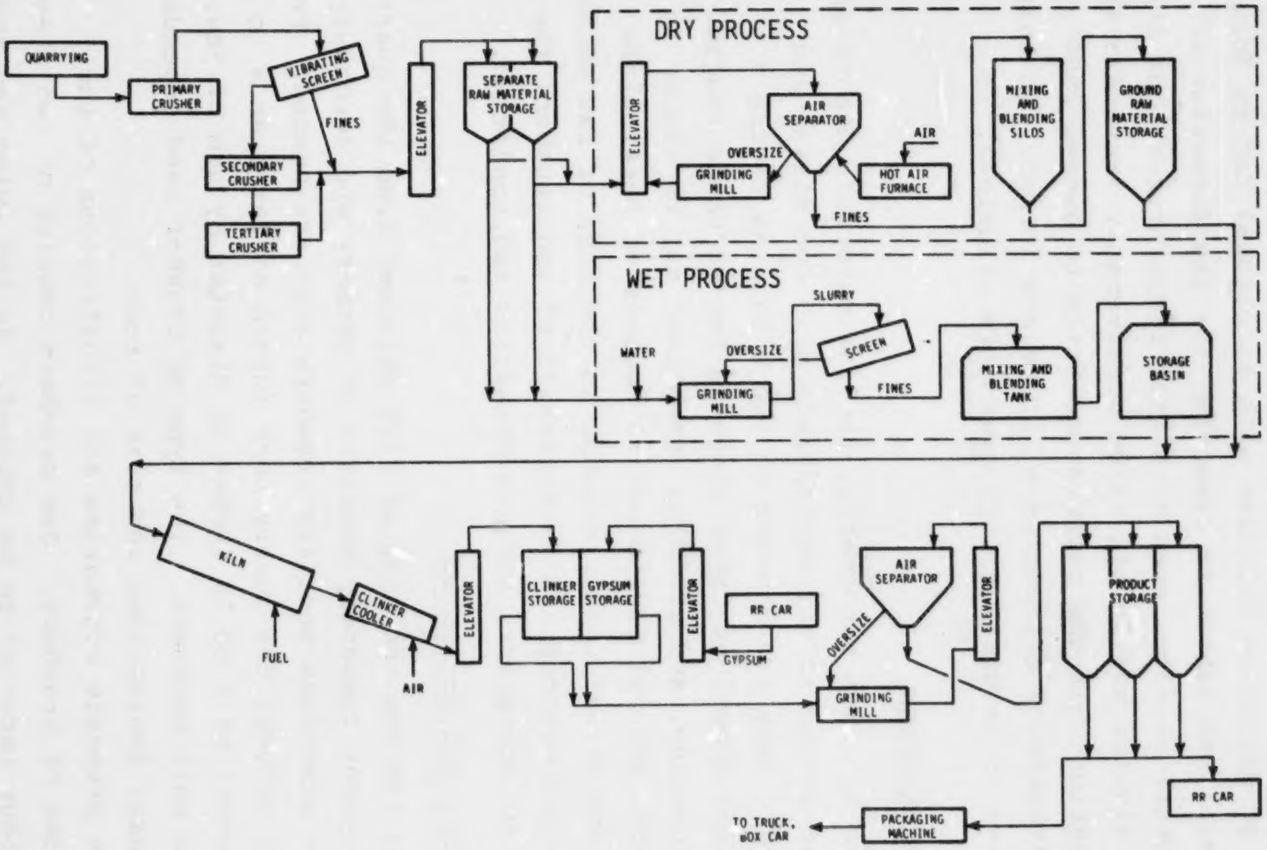
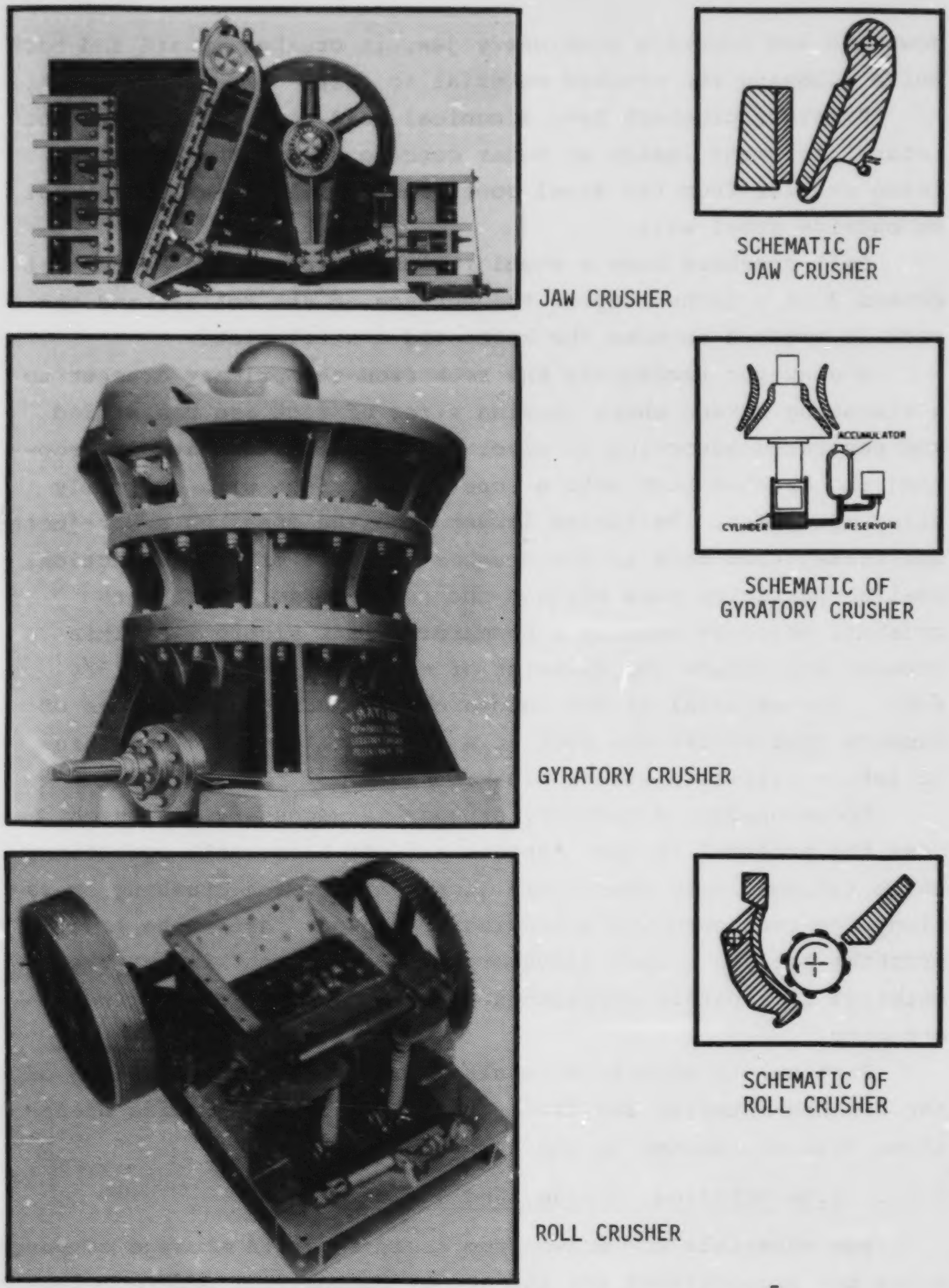

QUARRYING
PRIMARY CRUSHER
VIBRATING SCREEN
FINES
SECONDARY CRUSHER
TERTIARY CRUSHER
ELEVATOR
SEPARATE RAW MATERIAL STORAGE
DRY PROCESS
ELEVATOR
AIR SEPARATOR
OVERSIZE
GRINDING MILL
AIR
HOT AIR FURNACE
FINES
MIXING AND BLENDING SILOS
GROUND RAW MATERIAL STORAGE
WET PROCESS
SLURRY
WATER
OVERSIZE
GRINDING MILL
SCREEN
FINES
MIXING AND BLENDING TANK
STORAGE BASIN
KILN
FUEL
CLINKER COOLER
AIR
ELEVATOR
CLINKER STORAGE
GYPSUM STORAGE
ELEVATOR
RR CAR
GYPSUM
AIR SEPARATOR
OVERSIZE
ELEVATOR
GRINDING MILL
PRODUCT STORAGE
RR CAR
PACKAGING MACHINE
TO TRUCK, BOX CAR

Figure 5. Schematic diagram of portland cement process flow.[4]


ACCUMULATOR
CYLINDER
RESERVOIR

JAW CRUSHER

SCHEMATIC OF JAW CRUSHER

GYRATORY CRUSHER

SCHEMATIC OF GYRATORY CRUSHER

ROLL CRUSHER

SCHEMATIC OF ROLL CRUSHER

Figure 6. Types of primary crushing equipment.[5]

downward and toward a stationary jaw, it crushes upward and back while allowing the crushed material to exit.

Gyratory crushers have a conical head with a gyratory (not rotary) movement inside an outer concave bowl. The crushing force results from the steel cone pressing the material against an outside steel wall.

Roll crushers have a steel roller equipped with knobs that extend 3 or 4 inches beyond the surface of the roller, and the rock is crushed between the knobs and a steel plate.

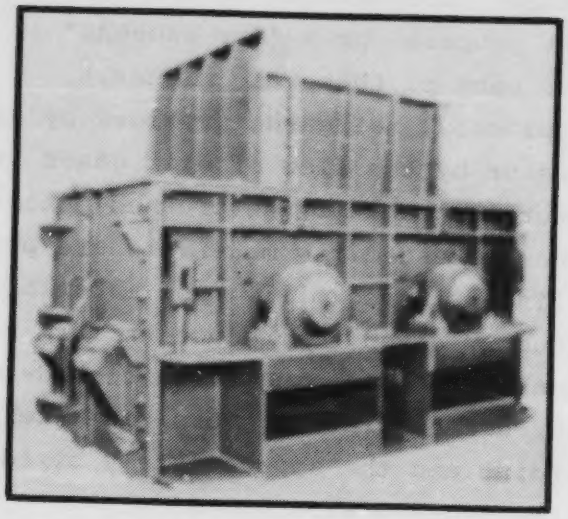
A conveyor transports the rock from the primary crusher to a vibrating screen where varying sizes of rock are classified and separated according to size. The process consists of dropping the crushed rock onto a screening surface with uniformly sized apertures. Particles larger than the openings are rejected and transported back to the crusher for further size reduction. Smaller particles pass through the openings to a secondary crusher, which is usually a hammermill (see Figure 7). This crusher can reduce the diameter of the rock to less than 3/4 inch. The material is fed into a chute leading to a series of hammers that strike the rock at a high rate of speed and force it into a collision with a breaker plate.[5]

Occasionally, a tertiary crusher is necessary, in which case the material is sent through a finer hammermill operation, which reduces it to about 5/16 inch. After each crushing operation, the rock enters a screening operation. After the last crushing step, a bucket elevator transports each kind of raw material to separate compartments for storage prior to fine grinding.

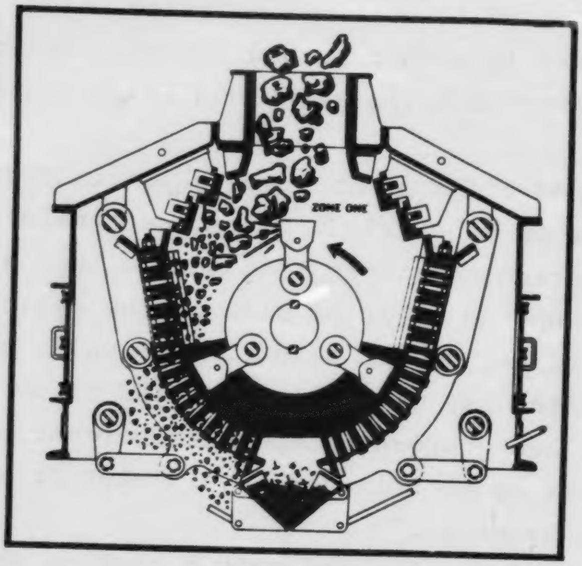
Particulate emissions result from the open transporting of the crushed material and from the crushing and screening operations that are vented to the atmosphere.

3.2.2 Fine Grinding, Mixing, and Blending

Raw materials are drawn from their separate storage compartments and proportioned for the proper composition before being



HAMMERMILL



SCHEMATIC OF
HAMMERMILL

Figure 7. Secondary crusher of the hammermill design.[5]

charged to the kiln. Composition of the feed material depends on whether a "wet process" or a "dry process" is to be used. (Figure 5 depicts each of these techniques.)

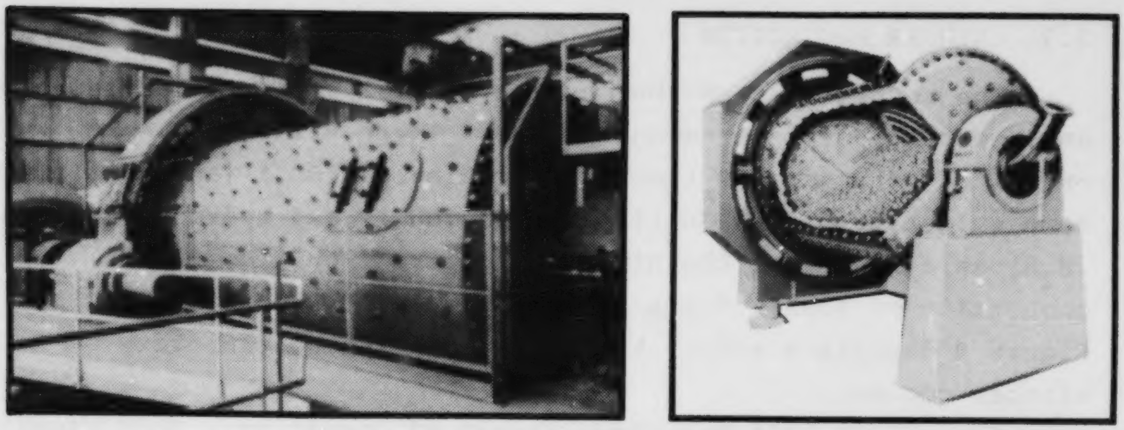
In the dry process, hot gases provided by direct-firing of separate furnaces or by the flow of exit gases from the kilns reduce the moisture content of the crushed material to less than 1.0 percent. These crushed raw materials are proportioned as they enter the fine grinding mill. The material must be finely ground and thoroughly mixed to produce uniform clinker composition (the end result of kiln calcining). In closed-loop operations, air separators or screens return oversized material to the mill for further grinding and the appropriately sized fraction is transported to the storage area.

In the wet process, crushed raw materials and water are fed to a fine grinding operation. The resulting slurry, which is about one-third water, is discharged from the mill and stored in open tanks, where additional mixing takes place. From the tanks, the slurry is either pumped directly to the kilns or dewatered first so that the kiln feed is approximately 65 percent solids.[6]

Ball and rod mills of the type shown in Figure 8 are used in both methods of fine grinding. These consist of cylindrical shells with protruding ridges that move either steel balls or rods partially up the interior side of the cylinder as it rotates at 15 to 18 revolutions per minute. The balls or rods cascade back down into the raw material and grind it to a fine consistency. The mills are charged to about 45 percent of their volume with steel balls up to 5 inches in diameter or with steel rods 2 to 5 inches in diameter.[5]

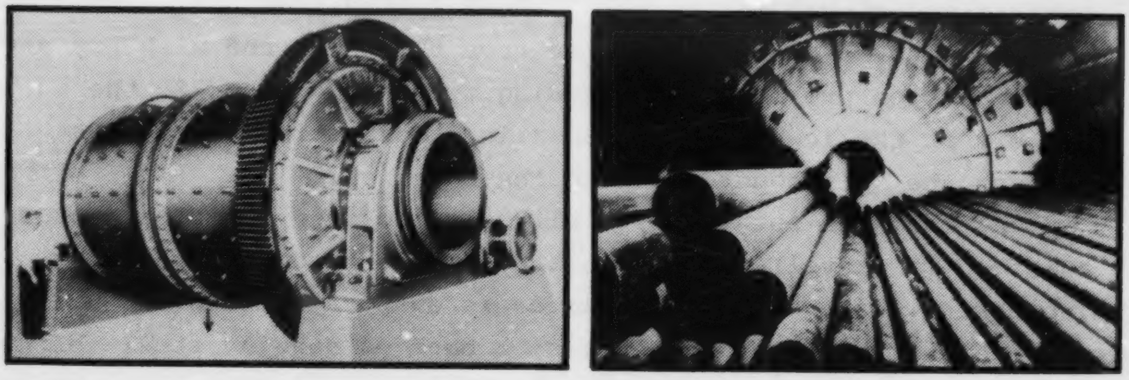
Particulate emissions are only a problem in the dry grinding and air separation processes; the water retains the particles in the slurry during wet grinding.

In the dry process, mixing and blending of the finely ground material occurs in silos. Open tanks are used in the wet process.



BALL MILL

CUT-AWAY OF BALL MILL



ROD MILL

CUT-AWAY OF ROD MILL

Figure 8. Ball and rod mills used for fine grinding.[5]

3.3 CLINKER PRODUCTION

The rotary kiln is the major potential source of atmospheric emissions at portland cement plants. These kilns also emit oxides of nitrogen (NO_x) and sulfur dioxide (SO_2) [and possibly some sulfur trioxide (SO_3)], ammonia (NH_3), and hydrogen sulfide (H_2S) as a result of the high temperature (2600° to 3000°F) combustion of fossil fuels and the nature of the feed material. Figure 9 depicts a rotary kiln with an attached planetary clinker cooler.

The rotary kiln has three stages of operation: feed, fuel firing, and clinker cooling and handling.[4] The raw materials are fed into the elevated end of a slightly inclined refractory-lined steel cylinder which rotates at about 50 to 90 revolutions per hour. The kiln is usually 150 to 500 feet in length and 8 to 16 feet in diameter, although some may be considerably larger. The various burning zones within the kiln are lined with different types of refractory material to withstand the varying temperature ranges in the kiln. Fuel (pulverized coal, fuel oil, or natural gas) is blown in from the lower end with hot air that has been pre-heated by passing over the clinker in the coolers at the lower end of the kiln. Combustion gases pass through the kiln counterflow to the material.[1,6]

As the kiln rotates, its slightly inclined position causes the feed to travel slowly downward, and it becomes exposed to increasing heat. First, the water is evaporated with the aid of various types of heat exchangers; a bank of hanging steel chains (Figure 10) is one of the most common types. As the temperature of the charge increases, organic compounds are volatilized, sulfates are decomposed, and chlorides and alkali salts are partially volatilized. About midsection of the kiln, calcium and magnesium carbonates are decomposed and carbon dioxide is liberated. Calcium oxide and magnesium oxide are also formed. In the hot zone (2700°F), about 20 to 30 percent of the charge is converted to liquid. It is through this medium that the chemical reactions proceed and the material turns incandescent.

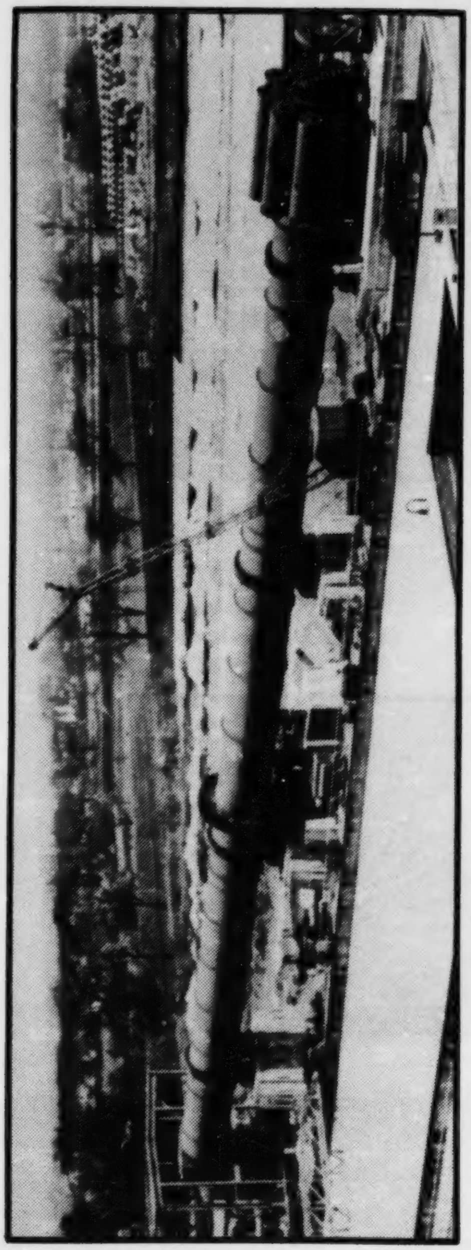
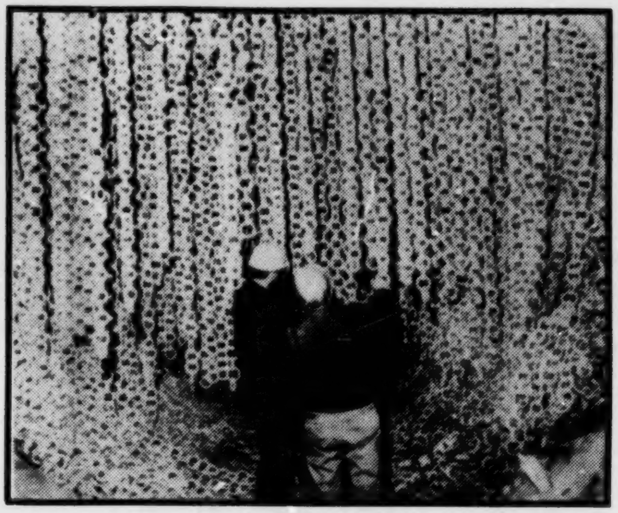


Figure 9. Rotary kiln with attached planetary clinker cooler.[5]



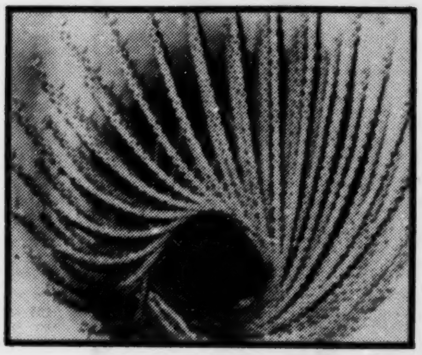


Figure 10. Two variations of hanging chains as a means of heat exchange in the kiln.[5]

At this stage, the clinker appears as round, marble-sized, hard glass balls.[1,6,7]

The kiln is a large source of particulate emissions and consumes large quantities of fuel (an average of one million Btu's are required to calcine one barrel of cement--376 pounds). Several design and operational changes are possible to reduce these tendencies. Design features that would reduce emissions include larger kiln diameters at the feed end and the addition of suspension preheaters. Enlarging the kiln diameter reduces the gas velocity and results in less dust entrainment. Suspension preheaters reduce emissions by feeding the raw material through a series of cyclones against an upward gas flow, which results in an effective countercurrent heat exchange.

Kiln designs vary. Some of the newer designs result in more efficient fuel combustion. The types of kilns used in the dry process are short rotary units (either with or without preheaters), rotary kilns with a suspension preheater, long rotary kilns with a built-in preheater, or an ACL kiln (Lepol) with double gas flow. The Lepol, a semidry process, is typical of traveling grate preheaters, where exit gas is used to heat a layer of pelletized raw feed spread on a traveling grate. Because the raw material is dried and preheated on the grate before entering the kiln, the combined length of the kiln and the grate is about 40 percent shorter than conventional units. This process reduces energy consumption to about 700,000 Btu's per barrel.[4]

Wet process kilns are either short kilns with cyclone preheaters or long kilns with internal chain preheaters. In the United States, rotary kilns are used, and most new plants use long kilns with chains or some other kind of preheating system. The chains have been proved effective for heat transfer and for improving fuel consumption. They are suspended in the preheating zone of the kiln and arranged so as to lift the slurry into the path of the hot gases and simultaneously to convey materials toward the burning zone.

Some preheating and heat exchange methods for energy conservation can also be used. The Humbolt preheater provides a series of cyclones through which the gases exiting the kiln pass before they reach the dust collectors. The dry feed enters the top chamber, falls through each cyclone, and is swept upward by moving gases. (The feed is heated to about 1380°F before reaching the kiln.)

The Mieg process allows exit gases and dust from the kiln to pass through a slowly rotating drum that contains heat exchange members. As the slurry passes through the drum, its moisture content is reduced from 30 percent down to 7 percent.

The Vickers desiccator is an enlarged section at the feed end of the kiln; the slurry passes over a double screw attached to the shell of the desiccator before entering the kiln. A section of similar length follows the screw and contains chains where the diameter tapers to normal. This system reduces the moisture content of the slurry from 40 percent to 8 percent.

The Holderbank heat exchanger consists of lifters that raise the charge and cascade it back through the hot gases. A vortex is produced by a row of guide vanes that increase the gas flow rate. This heat exchanger reduces fuel consumption by 21 percent.[1]

Depending on its alkali content, dust collected in the initial stages of the kiln control devices often can be returned to the kiln, which reduces disposal problems and the use of raw materials. Two methods used to return this dust are direct return by mixing with the kiln feed and direct return parallel to the kiln feed. The dust can also be returned by scoop feeders in front of the chain system or by use of a leaching system in which collected dust is mixed with large volumes of water and then dewatered to remove water-soluble alkali material before it is remixed with the kiln feed and spray impinged onto the chain system. Still another method is insufflation, which returns dry dust to the burning zone, either through the fuel pipe or by a separate pipe running parallel to the fuel pipe. This latter method results in about 8 percent fuel savings, but it can increase emission levels. No one method is satisfactory for all kilns. Figure 11 depicts these various methods of returning collected material to the kiln.

3.4 CLINKER COOLING

The clinker leaving the lower end of the kiln has a temperature of approximately 2700°F. The clinker cooler serves a dual purpose; it reduces the temperature of the clinker so that processing can continue; and it provides a means of recovering the heat from the clinker to preheat primary or secondary combustion air.

The three general types of coolers are shown in Figure 12. The early coolers were rotary coolers, which consisted of one-third refractory-lined cylindrical steel shells with lifters that raised, cascaded, and advanced the hot clinker through a stream of cooling air as it rotated. More recent designs are planetary (or multicylinder) coolers (attached to the kiln shell) and grate-type coolers. The planetary cooler consists of a series of tubes located around the circumference of the discharge end of the kiln which rotates with the kiln. The material flows from the kiln into the tubes which contain internal baffles that transfer heat from the material to the cooling air being pulled in. This heated air is returned to the kiln as preheated combustion air.

In a grate cooler, the hot clinker is cooled by passing air upward through the moving bed of clinkers on a perforated grate. The bed is uniform in thickness. Heat may be recirculated back to the kiln for preheating purposes.[5] Grate coolers are a source of particulate emissions because the air passing through the clinker bed is vented to the atmosphere.

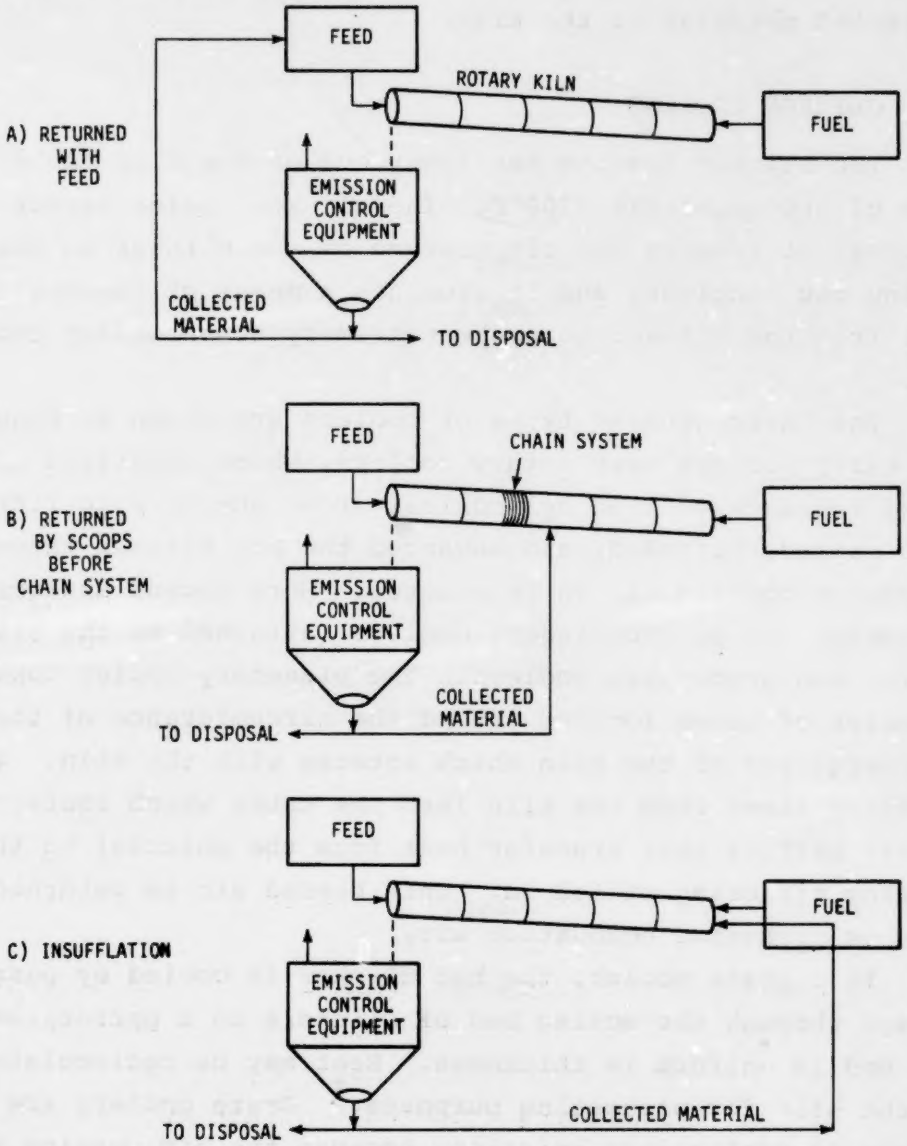
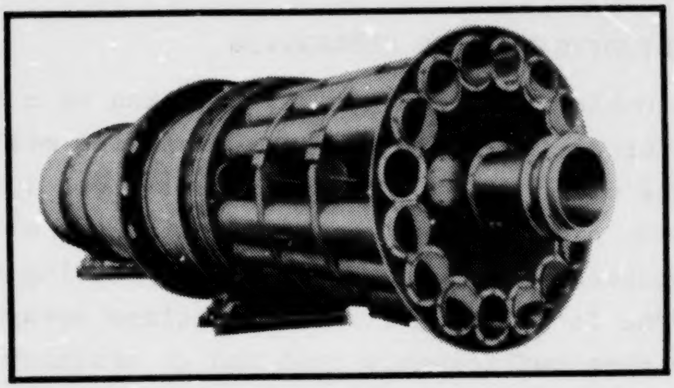
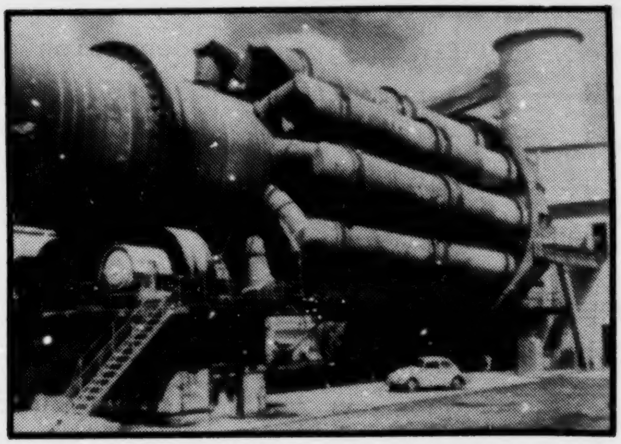

FEED
ROTARY KILN
FUEL
A) RETURNED WITH FEED
EMISSION CONTROL EQUIPMENT
COLLECTED MATERIAL
TO DISPOSAL
FEED
CHAIN SYSTEM
FUEL
B) RETURNED BY SCOOPS BEFORE CHAIN SYSTEM
EMISSION CONTROL EQUIPMENT
COLLECTED MATERIAL
TO DISPOSAL
FEED
FUEL
C) INSUFFLATION
EMISSION CONTROL EQUIPMENT
TO DISPOSAL
COLLECTED MATERIAL

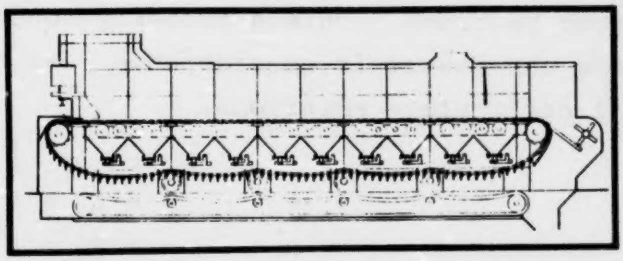
Figure 11. Methods of returning collected material to the kiln.



ROTARY CLINKER COOLER



PLANETARY CLINKER COOLER



TRAVELLING GRATE CLINKER COOLER

Figure 12. Types of clinker coolers.[5]

3.5 FINISH GRINDING AND AIR SEPARATION

From the cooler, the clinker may be taken to a storage area or transferred immediately to the finishing mills (see Figure 5). The mills are of the rotary ball type (previously described). The process consists of grinding the clinker with about 5 percent gypsum to regulate the setting time of the cement. The finishing mills are sometimes sprayed with water to keep them sufficiently cool and to minimize dehydration of the gypsum, which could lead to "false set" problems. The degree of fineness desired for the final product is controlled by air separators. Oversized material is returned to the mill for finer grinding.[1]

Uncontrolled, the finish grinding operation can contribute substantial amounts of particulate emissions. If control devices are used, the collected dust, which represents about 15 percent of the feed, is usable product. Transfer of the material after grinding can also generate fugitive emissions.

3.6 FINAL PRODUCT STORAGE, PACKAGING AND LOADING

Some of the product leaving the finish mills is conveyed to bulk storage silos, where it is held until bulk-loaded onto barges, tank trucks, or hopper bottom cars. Some is sent to a packaging building, where machines pneumatically load the finished cement into bags (94 lb/bag) and seal the bags for shipment by truck. Unless properly controlled, these operations can result in considerable loss of product and substantial particulate emissions.

SECTION 4

ATMOSPHERIC EMISSION CONTROL SYSTEMS

Atmospheric emissions from portland cement manufacturing processes can be controlled by a variety of add-on devices and by containment practices. Table 1 presents a summary of the control devices and their effectiveness on specific processes. As the summary shows, fabric filters are effective on most of the processes listed, whereas the other devices have limited application.

Appendix E provides a description of specific operating parameters and instrumentation necessary for proper operation of each control device.

Containment practices include either hooding or enclosing storage areas, processes, transfer points, and loading and unloading operations and application of water or chemical dust suppressants to storage piles and roadways to reduce fugitive dust.

4.1 ELECTROSTATIC PRECIPITATORS

4.1.1 Process Applications

Electrostatic precipitators can operate economically and at high control efficiencies on exhaust gas streams with high-volume flow rates (>20,000 cfm) and temperatures in the 300° to 600°F range. In the portland cement industry, they are used to control particulates in the exhaust gas flow streams from cement kilns and clinker coolers. If exhaust gas streams contain a large amount of moisture, such as those from wet process kilns and

TABLE 1. APPLICATION OF EMISSION CONTROL DEVICES TO PORTLAND CEMENT PROCESSES

Process	Effectiveness of emission control device[a]			
	Cyclone separator	ESP	Fabric filter	Gravel bed filter
Raw material crushing and grinding	Unsatisfactory	Impractical	Successful	Impractical
Calcining	Successful[b]	Successful	Successful	Impractical
Clinker cooling	Successful[c]	Successful	Successful	Successful
Finish grinding	Unsatisfactory	Impractical	Successful	Impractical
Product storage packaging and loadout	Unsatisfactory	Impractical	Successful	Impractical
General housekeeping and fugitive controls	Impractical	Impractical	Successful	Impractical

[a] Wet collectors are generally not used for portland cement processes.

[b] Preliminary cleaning only; used with ESP or fabric filter.

[c] In some states multiple cyclones are effective for achieving emission limits; in other states they are used in conjunction with an ESP or fabric filter.

clinker coolers, care must be taken to maintain the gas temperature well above the dewpoint to prevent condensation in the precipitator. Such condensation will not only cause corrosion of precipitator elements, but will also cause cement coating of the ESP interior and material bridging in the ESP hoppers. The gas temperature can be maintained above the dewpoint by designing to maintain a sufficiently high gas temperature to the ESP, by adequately designed insulation of the ducts and ESP surface,[6] and by the use of electric heaters and insulation on the surface of the particle collection hoppers.

4.1.2 Operating Parameters

Typical specific collection area (SCA) values range from 300 to 400 ft^2/1000 acfm for wet process precipitators[8,9] and from 200 to 500 ft^2/1000 acfm for dry process precipitators.[9] For a secondary current of 1000 milli-amperes, secondary voltages would typically vary from 40 to 50 kV for wet process precipitators[2] and from 20 to 30 kV for dry process units.[9]

If gas flow rate and temperature level are within design, high control efficiency of a precipitator can be maintained by a steady electrode voltage and efficient removal of collected particles from the plates and from the collection hopper. This latter effort minimizes sparking caused by excessive particle collection on the electrodes or the possibility of high levels of hopper material grounding plates and wires.

4.1.3 ESP Malfunctions and Inspection

Proper operation of an ESP depends on the proper design and on proper maintenance. Table 2 presents some of the more common problems associated with ESP operation. It is evident from this listing that most malfunctions result from lack of maintenance and attention to the system. Particularly notable are malfunctions caused by air leakage into the system and by inadequate removal of collected particles from electrodes and hoppers. All

TABLE 2. DETECTION AND SOLUTION OF ESP OPERATING PROBLEMS

Control panel indicators						
Primary voltage (a.c.), V.	Primary current, A	Secondary current, mA	Condition at precipitator/panel	ESP control efficiency,[a]	Possible problem	Problem solution
350[b]	40[b]	160[b]	Normal operation	Normal		
285	120	500	Gas volume and dust load dedecreases	Higher than normal		
400	30	140	Dust load increases	Usually, higher than normal		
350-400	40-150	100-700	In wet processes, temperature increases but resistivity is constant. In dry processes, temperature and resistivity increase	Higher than normal for wet processes, but lower than normal for dry processes		
240	40	200	Gas temperature decreases	Normal unless below dew point		Raise process temperature.
240	170	400	Arcing between electrodes	Less than normal	Higher hopper level Dust bridging in hopper	Increase dust removal rate. Use hopper vibrator.
400	40	160	Added primary voltage is required to maintain constant current; spark rate increases	Less than normal	Failure of discharge electrode rapper to remove dust buildup from electrodes	Increase rapping intensity. Repair rapper system.

(continued)

TABLE 2 (continued)

Control panel indicators						
Primary voltage (a.c.), V.	Primary current, A	Secondary current, mA	Condition at precipitator/panel	ESP control efficiency,[a]	Possible problem	Problem solution
240	40	160	Less primary voltage is required to maintain constant current. Spark rate increases	Less than normal	Failure of rapper on collection plate to remove dust buildup	Increase rapping intensity. Repair rapper system.
0-350	0-40	0-160	Violent fluctuation of indicators; high arcing noise	Zero to normal	Broken electrode with top part swinging back and forth	Isolate section until electrode can be replaced.
0	120	0	No current flow to precipitator	Zero	Electrical short circuit of transformer-rectifier (T-R) set, or wire grounded out	Repair or replace T-R set.
			High spark rate	Less than normal	Air leakage through inlet ductwork. Air leakage through inspection hatches	Seal points of leakage. Seal hatch doors.
			Corrosion (internal inspection)	No immediate effect	Inlet gas at temperatures less than dewpoint Problems encountered during startup and shutdown of kiln	Maintain gas temperature above dewpoint. Use insulation and hopper heaters.

[a] The effects of precipitator problems can only be stated on a qualitative basis.

[b] Multiple field ESP: primary voltage decreases in moving from inlet to outlet fields, and primary current increases in moving from inlet to outlet fields.

the malfunctions listed will decrease the particulate removal efficiency. Although the degree of efficiency loss resulting from a specific malfunction cannot be assessed, such loss will be reflected by increased opacity of the exhaust gas stream and higher particulate concentrations in stack emissions.

Many malfunctions can be determined only by an internal inspection of the ESP, which can take place only when the unit is deactivated and locked out to prevent inadvertent reactivation. The unit must also be satisfactorily purged and cooled before the inspector enters. Plant personnel should accompany the inspector, and someone should be stationed outside the unit in case of an emergency inside.

During external inspections, the inspector should record the primary and secondary voltage, current rate, and spark rate for each section, as shown in Figure 13. Later these values should be compared with values obtained during previous inspections and stack tests. If the spark rate meter is out of order, the rate may be estimated by noting the other gauges on the control panel, which will jump when the field sparks. When the spark meter is not operating, the inspector can determine the spark rate by counting the number of times these meters oscillate in 30 seconds and multiplying by 2.[10] A check of the daily log of readings will show whether readings are representative.

The inspector should also record rapping frequency and intensity. Irregular sounds from an individual rapper indicate improper operation or damage. He or she also should note inoperative meters, the number of power supplies on manual control, and power supplies on automatic control that are set for operating voltages below design specifications (sometimes done to reduce wire breakage).

The inspector should record the condition of the ESP relative to corrosion, leaks around seals or modules, number of electrical fields operating, etc., to set up a cause-and-effect relationship for inappropriate readings.

ESP ELECTRICAL DATA

Location	TR set No.	Primary voltage, V		Primary current, A		Secondary Voltage, kV		Secondary current, mA		Spark rate, sparks/min	
		Present	Base	Present	Base	Present	Base	Present	Base	Present	Base
	1	420	420	60	60	19	20	800	500	7	
	2	340	340	160	160	38	40	900	1000	3	
	3	285	290	210	200	38	40	1000	1000	0	

Figure 13. Example of ESP electrical data checklist for a portland cement kiln.[8,10]

Opacities of the gas stream from the source controlled by the ESP should be recorded on the form previously described in Section 2. Operating parameters for the processes being controlled by the ESP also should be recorded on the form described in Figure 3 and provided in Appendix C. This provides a means for comparison against previously recorded data and design information.

Breakdowns or scheduled shutdowns provide an opportunity for the inspector to perform an internal inspection of the unit. An internal inspection enables the inspector to observe the condition of the collecting plates (warped or bowed) and the discharge electrodes (some wires may be missing), the condition of the gas distribution plate, corrosion of interior, and the build-up of dust on the collecting plates and discharge wires. Problems resulting from such conditions were addressed in Table 1 and should be carefully noted.

4.2 FABRIC FILTERS

Fabric filter systems are widely used at portland cement plants, for control of both large and small point sources of emissions.

4.2.1 Process Application

Fabric filters are applied to many portland cement production processes. Table 3 presents a listing of these applications together with operating temperatures, fabrics used, and air-to-cloth ratios. Temperatures range from ambient to 500°F, and all modes of bag cleaning are represented. Selection of bag fabric is based on the chemical and thermal capability of the fabric for the gas being handled. For example, fiberglass bags can withstand higher gas stream temperatures than cotton bags.

All types of collectors and cleaning methods described may use natural or synthetic filter media. Not all collector designs are adaptable to the use of relatively fragile fiberglass fabrics,

TABLE 3. APPLICATION OF FABRIC FILTERS IN THE PORTLAND CEMENT INDUSTRY

Operation	Exhaust temperature, °F	Type of bag cleaning	Air-to-cloth ratio, ft	Common bag material	Reference
Primary crushing	Ambient	Mechanical shaking	2-3	Cotton	8,11
Secondary crushing	Ambient	Reverse-air	2	Cotton	8
Grinding	Ambient to 225	Mechanical shaking	2.5-3	Cotton	11
Storage silos	Ambient	Mechanical shaking	3	Cotton	11
		Reverse-air	1.7-1.9	Cotton	8
		Mechanical shaking	1.0-2.9	Cotton or Dacron	12
Feeders, belt conveyors	Ambient	Mechanical shaking	3.5	Cotton	11
		Pulse-jet	7	Cotton	11
Kilns	500	Reverse-air	1.7	Fiberglass	11
Clinker cooler	350	Pulse-jet	5.0-7.1	Dacron	8,11
		Reverse-air	1.7	Fiberglass	11
Finish mills	170	Mechanical shaking	2.5	Dacron	11,12
Finish mills	200	Pulse-jet	6-8	Dacron	8,11
Air separators	200	Mechanical shaking	2.5	Dacron	11
		Pulse-jet	6	Dacron	11
Packing and bulk loading	Ambient	Mechanical shaking	1.9-3.5	Cotton or polypropylene	13,14
		Pulse-jet	7	Dacron	6,13
Coal dryer		Mechanical shaking	2	Dacron	13

which call for avoidance of undue flexing. Felted media are suitable for medium- and high-pressure cleaning methods that operate at higher air-to-cloth ratios on more rapid cleaning frequencies. Woven fabrics are largely applicable to mechanical shaking and low-pressure gas or reverse-air cleaning methods.

4.2.2 Operating Parameters

The air-to-cloth ratio used in cement plants depends on the filter cleaning method, the particle properties, grain loading, etc.; for example:

Bag cleaning method	A/C ratio range[11]
Mechanical shaking	2 to 3
Reverse-air	1 to 2
Pulse-jet	5 to 7

The operating pressure of a fabric filter designed according to these criteria is normally 2 to 10 in. H_2O when the filter is clean, and 2 to 3 in. higher when the filter is coated with dust. Therefore, monitoring fabric filter operation consists of checking the pressure drop across the system, the gas flow rate and temperature, and the opacity of the exit gases. Another important consideration is the moisture content of the exhaust gas especially under cold startup conditions. If the temperature of the gas falls below its dewpoint, condensation will occur within the filter. The undesirable effects of condensation are 1) corrosion of the structural metal components of the filter, 2) muddying and blinding of the fabric filter media, and 3) bridging of dust in the hopper. Methods of circumventing this problem are to insulate the filter housing and structural members and to maintain the gas temperature above its dewpoint by regulation of process conditions or preheating.

4.2.3 Fabric Filter Malfunctions and Inspection

Efficient operation of a fabric filter for particulate emission control depends on proper design, correct operating procedures, and efficient maintenance practices. Table 4 presents a listing of the potential causes for the malfunctioning of fabric filters.

Although some problems are caused by improper design or selection of components, many of the problems are associated with the operation and maintenance of the filter system. If care and attention are given to the operation and maintenance for the system, chances are good that the system will operate efficiently. Failure to operate and maintain the system properly will result in frequent filter downtime and atmospheric emissions of gases with high particulate content and opacity.

While conducting the external inspection of a fabric filter, the inspector should record production information such as induced fan current and speed, gas temperature, and other information specified earlier in Figure 3 and on the forms provided in Appendix C. Pressure drop and opacities for each of the compartments in the fabric filter should also be recorded. Manometers or gages located on the units shown provide both clean-side and dirty-side readings. The inspector should also use visual observations to determine if there are leaks around seals, compartments, etc., and note any findings.

If an internal inspection is conducted, the same safety precautions apply as those for ESP inspections. Problems to look for are excess dust buildup on the clean side of the filter, bag deterioration at the bottom thimbles, dryness of the filter cake, plugging or corrosion problems in the hopper, and missing or broken bags. The inspector should record all of this information to provide a basis for poor equipment operation if such be the case.

4.3 CYCLONE SEPARATORS

Use of cyclone separators has been somewhat limited in the portland cement industry. These separators are relatively inexpensive and easy to operate, but they cannot readily achieve high efficiencies in the removal of small particles.

TABLE 4. FABRIC FILTER MALFUNCTIONS AND REMEDIES[15]

Problem	Possible cause[a]	Remedy
High stack opacity	Bag holes	Replace bags. Tie off bags and replace at a later date. Isolate leaking compartment, if allowable without upsetting system.
	Bag bleeding	Reduce gas volume (A/C).
	Insufficient filter cake	Allow greater dust buildup on bags by cleaning less frequently.
High filter pressure drop	Bag cleaning mechanism not adjusted properly	Increase cleaning frequency. Clean for longer duration. Clean more vigorously (check with manufacturer before implementing).
	Cleaning time failure	Check to see if timer is indexing to all contacts. Check output on all terminals.
	Failure to remove dust from bags	Send sample of dust to manufacturer. Send bag to lab for analysis for blinding. Dryclean or replace bags. Reduce air flow.
	Incorrect pressure reading	Clean pressure taps. Check hoses for leaks. Check for proper fluid in manometer. Check diaphragm in gage.
High bag failure: wearing out	Baffle plate erosion	Replace baffle plate.
	High grain loading	Install primary collector.
	Cleaning cycle too frequent	Slow down cleaning cycle.
	Shaking too violent (S)	Slow down shaking mechanism (consult manufacturer).

(continued)

TABLE 4 (continued)

Problem	Possible cause[a]	Remedy
	Repressuring pressure too high (RF)	Reduce pressure.
	Pulsing pressure too high (PJ)	Reduce pressure.
High bag failure:	Failure of cooling device	Replace thermocouple
High bag failure: decomposition	Operating below acid dew point	Increase gas temperature. Bypass on startup.
Moisture in baghouse	System not purged after shutdown	Keep fan running for at least 10 minutes after process is shut down.
	Wall temperature below dewpoint	Raise gas temperature. Insulate unit. Lower dewpoint by keeping moisture out of system.
	Compressed air introducing water (PJ)	Check automatic drains. Install aftercooler. Install dryer.
Material bridging in hopper	Moisture in baghouse	See above. Add hopper heaters.
	Dust being stored in hopper	Remove dust continuously.
	Hopper slope insufficient	Modify or replace hoppers.
	Conveyor opening too small	Use a wide-flared trough.

[a] The following code is used to refer to the specific type of fabric filter:

RF = Reverse-flow cleaning mechanism
PJ = Pulse-jet cleaning mechanism
S = Shaker cleaning mechanism

4.3.1 Process Applications

Because of its inherent removal-efficiency limitations, the cyclone separator is used by itself only on the clinker cooler, where the particle size range of the emissions is sufficiently large that achievement of up to about 95 percent removal efficiency is possible.[16,17]

The cyclone separator is also used as an auxiliary control device for effluent gases from operations such as kilns and finish mills. In these applications, the gases are sent first through a cyclone separator and then through a high-efficiency removal device such as an ESP or a fabric filter. Even though the cyclone separator's control efficiency is only 50 to 75 percent, by reducing the amount of dust entering the high-performance device, it permits more efficiency for that device. The large dust fraction removed by the cyclone is easily recyclable if desired. Its use can also extend the useful life of major control devices by reducing the wear from abrasion and erosion to which they might otherwise be subjected.

4.3.2 Operating Parameters

Pressure drop for a cyclone separator is normally designed for a range of 2 to 5 in. H_2O at the design gas flow rate. If the operating gas flow rate is much lower than design flow, the differential pressure across the separator will decrease markedly, as will the separation efficiency. If gas flow is appreciably greater than design flow, the pressure drop across the separator will increase, but the separation efficiency will decrease as a result of gas bypass within the separator and dust re-entrainment.

4.3.3 Malfunctions and Inspection

Anything that interferes with the proper gas flow through the cyclone separator will decrease separator efficiency. Table 5 lists the various symptoms of gas flow malfunction, together with possible causes and suggested remedies.

TABLE 5. CYCLONE SEPARATOR MALFUNCTIONS AND REMEDIES

Symptoms	Possible causes	Remedies
Low pressure differential	Low process gas flow	For multiple-cyclone installations, damper off flow to some units.
	Erosion or corrosion of tubes causing gas to short-circuit cyclone	Replace defective tubes.
High pressure differential and high stack opacity	High process gas flow or plugged cyclone tubes	Add more separators and clean out tubes.
	Air inleakage	Seal leaks.
High stack opacity	Separator inefficiency due to:	
	High dust level	Increase speed of discharge valve.
	Dust bridging due to moisture condensation	Insulate separator and heat hopper.
	Separator vane or tube wear by abrasion	Replace components with abrasion-resistant materials.

Because operation of the cyclone separator is relatively simple, malfunctions are generally minimal. The major problems are high dust levels in the hopper or moisture condensation in the hopper (which causes plugging). The use of a hopper level indicator, hopper heating, and separator insulation helps to avoid these problems. Blockage of the cyclone tube, especially on those with smaller diameters (~4 inches), can also be a problem.

An external inspection of the cyclone helps to determine possible leaks at joints, inspection doors, or corroded areas. Leakage of air into the cyclone disrupts the internal gas flow pattern and decreases the cyclone's efficiency. This inspection will also reveal any plugged and eroded tubes and eroded inlet vanes. The system must be turned off, thoroughly purged, and cooled before an internal inspection is made.

4.4 GRAVEL-BED FILTERS

Gravel-bed filters have been used successfully in the portland cement industry for many years, although their application is limited.

4.4.1 Process Application

A gravel-bed filter control system consists of 6 to 20 modules, each of which may contain from one to three gravel beds. Figure 14 shows a typical modular arrangement. All modules are one standard size; for a two-bed arrangement they have an outside diameter of 9 ft, 2-5/8 inches and a straight shell height of 24 ft, 7-1/2 inches.[18] The gravel beds have an effective flow area of 40 square feet each.*

The one process point in a portland cement plant where the gravel-bed filter has been widely used is the clinker cooler. The cooler is frequently subjected to process upsets that cause

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* Personal communication between D. J. Loudin, PEDCo, and R. Schumway, Rexnord Corp., November 19, 1981.

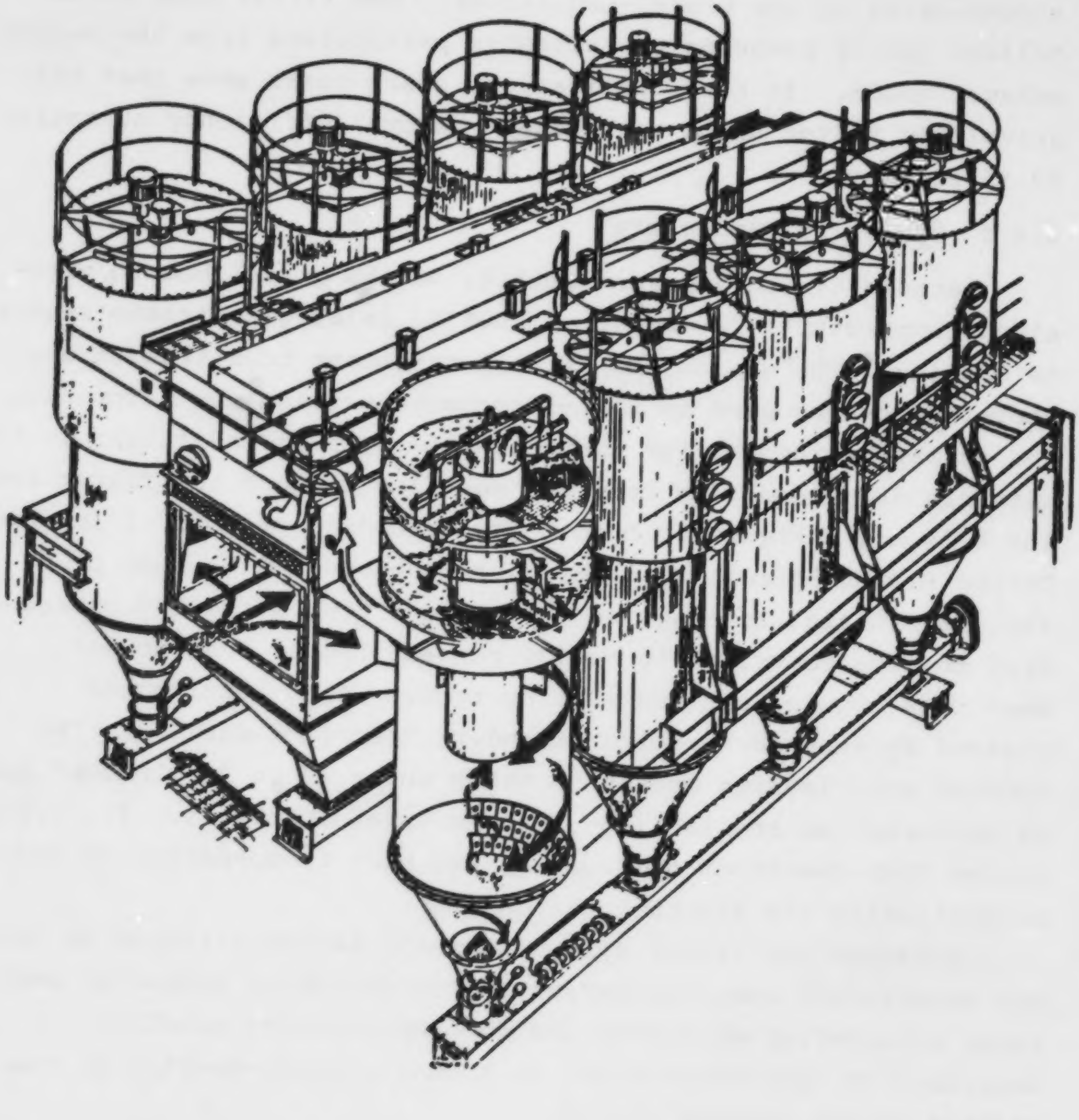

Figure 14. Representative arrangement of gravel-bed filter modules. (Courtesy of Rexnord Corporation)

high-temperature-gas excursions, a condition that is easily accommodated by the gravel-bed filter. The filter does an excellent job of removing the abrasive particulate from the cooler exhaust gases. In this application, stack tests show that the gravel-bed filter has a particulate removal efficiency averaging 99.85 percent.[19]

4.4.2 Operating Parameters

Because of the inherent ability of the gravel bed to withstand temperatures in excess of 1000°F, inlet gas streams require no cooling. The gravel bed is also resistant to attrition and therefore can be used to filter abrasive particulate materials. The primary parameter for operation of a gravel-bed filter is the pressure drop resulting from the gas flow through the filter bed. The beds are designed to have a pressure drop of 6 to 12 in. H_2O. During filter operation, particulate captured on the bed plugs the interstitial openings in the bed and causes the bed pressure drop to rise to values 50 to 100 percent higher than normal. When this occurs, the bed must be removed from service and cleaned by the backflushing procedure described earlier. The removal and cleaning operation takes about 12 to 20 minutes* and is performed at regular (45- to 60-minute) intervals. The transition from operation to cleaning and back to operation is made automatically via instrumentation.

Although the filter system normally is not affected by inlet gas temperature and flow surges, these variables should be monitored as a matter of record and good engineering practice. Recorders or indicators would be normally panel-mounted at the clinker cooler control station.

The pressure differentials across each of the modules also should be monitored, as the differential indicates the condition of the gravel bed. The differential pressure gages are locally mounted at each module and calibrated from 0 to 30 in. H_2O.

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* Personal communication between D. J. Loudin, PEDCo, and R. Schumway, Rexnord Corp., November 19, 1981.

Other instrumentation required by gravel-bed filters are cycle timers and controls for the dampers that direct the entry of backflushing gas to the individual filter modules. Damper positions are indicated on a control panel for the system, but damper activators are locally mounted at the module.

4.4.3 Malfunctions and Inspection

Because of the relative simplicity of this particulate control system, most installations have a history of trouble-free operation. A couple of installations, however, have had temperature-related malfunctions that resulted in damage to the filter-bed equipment and subsequent increases in particulate emissions.

In one case, a system designed for a working temperature of 400°F was subjected to long-term exposure of temperatures above 1000°F.[20] The resulting metal expansion caused the rabble arms used to turn the bed during the cleaning cycle to tear the gravel-bed support screen.

At another installation, the use of ambient temperature air for backflushing the filter modules caused thermal stress cracks to develop within the modules, which allowed dust-laden gas to contaminate the clean gas stream.[11] Use of hot recycled clean gas instead of ambient air for backflush eliminated the thermal shock to the filter system and the subsequent cracking of the internals of the modules.

Moisture in the backflush gas or air is also a problem for gravel-bed filters. Rain may enter through breaks in the ductwork or flanges and be transmitted into the gravel beds. When water enters a bed, it hydrates the cement dust and can cause the bed to solidify. Therefore, a program of frequent checking and preventive maintenance should be set up to prevent leakage into the system.

During an external inspection of the gravel-bed filter, the inspector should record the pressure differential for each of the modules in the assembly and the opacity of gas from the stacks. In addition to gas temperature and gas volume, production information should be recorded for the clinker cooler being controlled. These should be recorded on the form provided in Appendix C.

An internal inspection permits the inspector to observe and record the condition of the support screen and other internal members for signs of cracks or fatigue. The inspector also should note any inleakage problems or clogging in the isolating valves or screw conveyor for removing collected material.

4.5 CONTAINMENT AND DUST SUPPRESSION PRACTICES

Many portland cement processes are not vented to emission control equipment. Because of the volume of material processed, these sources have the potential of contributing significant amounts of atmospheric emissions. Containment and dust suppression practices prevent these sources from generating excessive emissions, however.

Feeding, transfer, and discharge operations are all sources of emission problems, and spilled product and wind are responsible for entrainment of the dust. Most of the entrained dust results from spillage and agitation of material at the transfer points. (Movement of clinker, particularly from the coolers, is one of the worst transfer problems.) Such emissions are contained by either enclosing or hooding these transfer points. Incomplete enclosure, however, sometimes enhances the problem by creating a wind tunnel effect.

Loading and unloading operations of both raw materials and final product create an emission problem because of the mechanical agitation of the material as it strikes the sides and bottom of the receiving vessel and because of displaced air during loading or unloading. Gusting winds can intensify this problem. Various containment practices are used, frequently in combination. Such practices include enclosing the operation, choke-feeding or using a telescoping chute to limit the free-fall distance of the material, and using movable hoods ducted back into the unloading vessel.

Potential emission problems result from spilled product, mud trackout from heavy equipment, and roadway and parking surface deterioration. This material becomes reentrained by contact with vehicle tires and air turbulence caused by passing vehicles. This dust can be controlled by the use of sweeper trucks and the application of water or oil coatings.

Dusting from storage piles occurs when the material is dumped onto the pile and when wind blows across the pile. Containment methods are enclosure of the storage area or the application of water or chemical dust suppressants to the material. Enclosure should be complete to prevent a tunneling effect from the wind. The type of material stored determines which method should be used (e.g., the application of water is not a suitable containment method for stored finished cement). Use of telescoping chutes is also an effective containment practice during the dumping of material onto these storage piles.

Disposal of material collected by the control devices also can be a source of emissions. The disposal process consists of loading, unloading, and transporting of the waste, and each can generate emissions. Containment methods for loading include enclosing the loading area and reducing the free-fall distance into the disposal vehicle. Containment in transport can be accomplished by the use of an enclosed vehicle. Containment during the unloading of the waste at the disposal site can be accomplished by reducing the free-fall distance and covering or chemically stabilizing the material at the site to prevent wind erosion. Table 6 summarizes the various containment practices.

During the inspection, the inspector should note whether these operations are causing a fugitive dust problem. If possible, visible emission readings should be obtained and recorded on the appropriate form (Section 2). It may be possible for the inspector to observe some containment methods in practice during the inspection; if so, the success of the practice should be noted.

TABLE 6. DUST SUPPRESSION PRACTICES

Operation	Enclosing	Hooding	Telescoping or choke-feeding	Chemical or water spray
Transfer and conveying	X	X		
Loading and unloading	X	X	X	
Paved and unpaved roadways				X
Storage piles	X		X	X
Disposal	X		X	X

Table 7 provides a summary indicating the magnitude of the fugitive emissions problem at portland cement plants. It includes fugitive emission factors and an inventory of emissions obtained during the inspection of a portland cement plant.

TABLE 7. QUANTIFICATION OF FUGITIVE EMISSIONS FROM PORTLAND CEMENT MANUFACTURING

Source	Uncontrolled fugitive emission factor	Plant fugitive emission inventory	
		Operating parameter, tons/year	Uncontrolled emissions,[a] tons/year
Raw material unloading	0.03-0.4 lb/ton	177,576	19
Transfer points and associated conveying	0.2-0.4 lb/ton	651,338	98
Unloading outfall to storage[b]	3.0-5.0 lb/ton	650,687	1,300
Raw blending[c]	0.05 lb/ton	649,355	13
Unloading--clinker/gypsum outfall to storage[d]	5.0-10.0 lb/ton	446,059	1,671
Cement silo vents	Negligible	-	-
Cement loading	0.236 lb/ton	413,485	49
Cement packaging	0.01 lb/ton	30,980	Negligible
Paved and unpaved roads	6.1 g/VMT[e]	-	-

[a] Based on average of emission factors.

[b] Emissions include raw material storage and transfer to conveyor.

[c] Emissions include blended materials storage.

[d] Emissions include clinker/gypsum storage and loadout.

[e] Grams per vehicle miles travelled.

SECTION 5

PLANT OPERATING CONDITIONS AND COMPLIANCE DETERMINATION

The plant inspection effort will depend on the main purpose of the inspection. While a detailed internal and external inspection of all process and control equipment could take a few days, a "walk through" inspection, where only major emission sources are observed, can be accomplished in less than one day.

The main potential emission problem areas in any cement plant relate to the calcining operations and their control. The kiln and its control system should thus be carefully inspected. Inspection of material handling systems should receive the next highest priority followed by the various crushing and grinding operations. Table 8 provides a summary of items to be observed, and Figure 15 is an inspection checklist to be used during the inspection.

5.1 PROPER OPERATING CONDITIONS AND EMISSION PROBLEMS DUE TO PROCESS MALFUNCTIONS AND UPSETS

The inspector should be able to distinguish between a smoothly operating plant and one that is experiencing malfunctions or upsets that could lead to excess atmospheric emissions.

Movement of raw materials from quarrying operations should occur without entraining fugitive dust, either from vehicle movement in the plant or from the dumping of the raw material. The delivered raw material should be stored in an enclosed area so that wind cannot dislodge loose particles and create a fugitive dust problem. If necessary, the stored material should be sprayed with a dust suppressant. Dust generation is generally a function of the type and moisture content of the raw materials.

TABLE 8. SUMMARY OF INSPECTION POINTS

Operation	Inspection items
Kilns and clinker coolers	Production rate Exhaust gas flow rate and temperature Percent O_2 in exhaust gas Fuel type, firing rate, and composition in the kiln Degree of dust recycled to the kiln
Kiln and clinker cooler emission control systems	Opacity Leaks in control system housing (corrosion and other reasons) ESP voltage and power levels Pressure drop across control equipment Exhaust flow rate and temperature Percent O_2 in exhaust gas Rapping frequency and intensity in ESP Operative vs. inoperative instruments Manual vs. automatic ESP power supplies Operative vs. inoperative ESP fields Internal observations (wires, bags, tube blockage, full or plugged hopper, efficiency of cleaning operation, etc.) Moisture content of gas stream Fan current and speed for flow calculations
Material handling systems	Placement and condition of covers and hoods Operation of exhaust fans Evidence of spills and leaks Opacity of exhaust air Volume of material handled Fugitive emissions Handling practices
Crushing and grinding systems	Covers and seals in position Evidence of leaks Volume of material handled Exhaust gas flow rate Opacity of exhaust gas Material handling practices Fugitive emissions If controlled: pressure drop across device Full or plugged dust collection hoppers Internal observations (bags, tube blockage, efficiency of cleaning operation)

Name of company: ______________________________

Address: ______________________________

Responsible person: ______________________________

Date of inspection: ______________________________

Time in: ______________ Time out: ______________

Inspection group: ______________________________

Production Equipment[a]

A. Kiln

Slurry feed rate _____ tons/h

Dry solids feed rate _____ tons/h

Moisture content _____%

Feed end temperature _____°F

Burner end temperature _____°F

Firing rate _____ 10^6 Btu/h

Firing rate (coal) _____ tons/h

(oil) _____ tons/h

(gas) _____ tons/h

If ESP control:

Inlet temperature _____°F

ID fan current _____ amperes

ID fan pressure drop _____ in. H_2O

ID fan speed _____ rpm

(calculated) gas volume _____acfm

Oxygen content (ESP exit) _____%

Outlet temperature _____°F

Power output:	1°current	1°voltage	2°current	2°voltage
No. 1 Field				
No. 2 Field				
No. 3 Field				
No. 4 Field				

Corona power _____ watts

Specific power density _____ watts/10^3 acfm

Rapper condition _____

Hopper discharge _____

Kiln rotation rate _____ rev/h

Carbonate content _____%

Alkali content _____% (Na, K)

Water cooling rate _____ gal/min

Clinker production rate _____ tons/h

Insufflation rate _____

Recycle rate _____

Oxygen content _____%

Opacity _____%

If Fabric Filter Control:

Inlet temperature _____°F

ID fan current _____ amperes

ID fan pressure drop _____in. H_2O

ID fan speed _____rpm

(calculated)gas volume _____acfm

Outlet temperature _____°F

Moisture content _____%

Pressure drop per compartment _____in. H_2O

Bag condition _____

If precleaner:

Inlet temperature _____°F

ID fan current _____ amperes

ID fan pressure drop _____in. H_2O

ID fan speed _____ rpm

(calculated) gas volume _____acfm

Moisture content _____%

---

[a] For information not applicable, indicate N/A.

Figure 15. Portland cement plant inspection checklist.

Figure 15. (continued)

Name of company: ______________________________

Address: ______________________________

Responsible person: ______________________________

Date of inspection: ______________________________

Time in: ______________ Time out: ______________

Inspection group: ______________________________

B. Clinker Cooler[a]

Clinker process rate _____ tons/h

Inlet temperature _____ °F

Outlet temperature _____ °F

Condition of equipment _____

Opacity _____ %

If ESP control:

Inlet temperature _____ °F

ID fan current _____ amperes

ID fan pressure drop _____ in. H_2O

ID fan speed _____ rpm

(calculated) gas volume _____ acfm

Outlet temperature _____ °F

Power output:	1°current	1°voltage	2°current	2°voltage
No. 1 Field				
No. 2 Field				
No. 3 Field				
No. 4 Field				

Corona power _____ watts

Specific power density _____ watts/10^3acfm

Rapper condition _____

Hopper discharge _____

If gravel bed control:

Inlet temperature _____ °F

Exhaust flow rate _____ acfm

Pressure drop per module _____ in. H_2O

If fabric filter control:

Inlet temperature _____ °F

ID fan current _____ amperes

ID fan pressure drop _____ in. H_2O

(calculated) gas volume _____ acfm

Outlet temperature _____ °F

Moisture content _____ %

Pressure drop per compartment _____ in. H_2O

Bag condition _____

If precleaner:

Inlet temperature _____ °F

ID fan current _____ amperes

ID fan pressure drop _____ in. H_2O

ID fan speed _____ rpm

(calculated) gas volume _____ acfm

Moisture content _____ %

[a] For information not applicable, indicate N/A.

(continued)

Figure 15. (continued)

Name of company: _____

Address: _____

Responsible person: _____

Date of inspection: _____

Time in: _____ Time out: _____

Inspection group: _____

B. Clinker Cooler[a]

Clinker process rate _____ tons/h

Inlet temperature _____°F

Outlet temperature _____ °F

Condition of equipment _____

Opacity _____%

If ESP control:

Inlet temperature _____ °F

ID fan current _____ amperes

ID fan pressure drop _____ in. H_2O

ID fan speed _____ rpm

(calculated) gas volume _____ acfm

Outlet temperature _____°F

Power output:	1°current	1°voltage	2°current	2°voltage
No. 1 Field				
No. 2 Field				
No. 3 Field				
No. 4 Field				

Corona power _____ watts

Specific power density _____ watts/10^3acfm

Rapper condition _____

Hopper discharge _____

If gravel bed control:

Inlet temperature _____°F

Exhaust flow rate _____ acfm

Pressure drop per module _____ in. H_2O

If fabric filter control:

Inlet temperature _____ °F

ID fan current _____ amperes

ID fan pressure drop _____ in. H_2O

(calculated) gas volume _____acfm

Outlet temperature _____ °F

Moisture content _____%

Pressure drop per compartment _____ in. H_2O

Bag condition _____

If precleaner:

Inlet temperature _____ °F

ID fan current _____ amperes

ID fan pressure drop _____ in. H_2O

ID fan speed _____ rpm

(calculated) gas volume _____acfm

Moisture content _____%

---

[a] For information not applicable, indicate N/A.

(continued)

Figure 15. (continued)

Name of company: ______________________________

Address: ______________________________

Responsible person: ______________________________

Date of inspection: ______________________________

Time in: ____________ Time out: ____________

Inspection group: ______________________________

C. Other Processes[a]

Process rate per unit:
Crushing ____________ tons/h
Grinding ____________ tons/h
Conveying ____________ tons/h
Mixing and blending ______ tons/h
Packaging, loading, and unloading ________ tons/h

Storage:
Raw material ________ tons
Processed material ______ tons
Finished product ______ tons

If fabric filter control: per unit

	Crushing	Grinding	Conveying	Mixing/ Blending	Packaging/ loading, Unloading	Storage
Inlet temperature ____ °F						
ID fan current ____ amperes						
ID fan pressure drop ____ in. H_2O						
ID fan speed ____ rpm						
(Calculated) gas volume ____ acfm						
Outlet temperature ____ °F						
Bag condition ____						
Opacity ____ %						
Pressure drop ____ in. H_2O						

[a] For information not applicable, indicate N/A.

Sometimes the material is extremely wet, in which case fugitive dust is not a problem. As the wet material enters subsequent crushing and grinding operations, however, wet bags in the fabric filters controlling these processes can create problems that render the control device ineffective.

In the crushing and grinding operations, fugitive dust can be released through leaks in worn seals around nuts and bolts in the walls of the crushers and grinders. Such leaks will occur regardless of the efficiency of a control device.[21] Fugitive emissions may also escape from the charging end of some crushers. Occasionally, crushers are enclosed to eliminate the dust problem, but in principle, the amount of fugitive dust generated depends on the type and moisture content of the raw material, and the type and characteristics of the crusher. Properly operated plants should be able to eliminate these potential problems.[6]

The transfer of material at various stages of processing is also critical. Leaks in conveying ductwork, hoods, and enclosures and spillage of material that can become reentrained by wind or vehicle movement can contribute substantially to fugitive emissions. Efficiently run plants, realizing how abrasive the material can be to equipment, correct these items by performing timely maintenance before they become a serious problem.

Leaks around seals and in ductwork also create problems in the mixing and blending operations. Preventive maintenance can reduce malfunction and upset occurrences in these operations.

The occurrence of malfunctions in the kiln system is not uncommon. For example, the introduction of improperly prepared feed material to the burning zone can increase kiln exhaust gas temperatures to the point that fabric filter bags are damaged and ESP collection plates become warped. Both of these problems increase atmospheric emissions.

Nonuniform feeding of the kilns also results in excess atmospheric emissions and less efficient kiln operation. A plugged feeding system can result in a loss of flame, which leads to incomplete combustion, a condition that can produce an explosion hazard in ESP's. (Occasionally combustion analyzers are wired to the ESP so that if an explosive condition exists, the ESP will be automatically deenergized.)

Spillage of feed materials also contributes to the generation of fugitive dust. Spilled material should be picked up and reused before becoming entrained via wind and vehicle movement in the area.

Leaks in the seals and ductwork ahead of the control system can result in excess emissions, for a control device cannot be effective unless the contaminated gases enter it. Inleakages can also be a problem, in that they lead to corrosion and excessive gas volumes to be handled by the equipment.

The injection of collected material from wet process kilns is a source of concern in that it contributes to the tendency for the cement dust to hydrate and solidify in the presence of the slurry water.[21]

A problem that occurs in the kiln itself results from a tendency of layers of particulate to build up and form rings on the inside of the kiln. This buildup decreases the cross-sectional area, which causes an unstable kiln flame. When these kiln rings break off, the clinker rolls down the kiln and causes heavy particulate loading. (Ring formation is considered to be a normal occurrence, not a malfunction.[6])

Malfunctions also can result from some of the preheating improvements used to reduce kiln emissions. For example, chains may break or suspension preheaters and grate preheaters may no longer operate efficiently and thus not fulfill their purpose.

Because of the abrasive nature of the material being processed, the inspector should check cyclones being used in clinker coolers for deterioration. The occurrence of excessive visible emission from the cooler probably also indicates a pollutant mass rate problem resulting from the large size of particles emitted by this process.

The abrasiveness of clinker can cause problems during the transfer of the product to storage. This abrasiveness can cause ductwork and storage vessels to develop leaks, and fans and bearings to become less efficient because of the wear, which can in turn result in spilled product becoming airborne and creating a fugitive dust problem. The use of telescoping or ladder chutes in storage areas to reduce freefall distances during clinker unloading is a means of reducing emissions, but to be effective, these devices must be free of splits, holes, or breaks.

Partially enclosed storage areas do not eliminate dust entrainment resulting from wind and loading and unloading operations. Complete enclosure is necessary.

The inspector should note the method used to dispose of collected particulate not returned for processing. The use of open trucks (a common occurrence) results in reentrainment of the collected material. The proper removal method is by enclosed trucks. Over-loaded collection hoppers also can result in inefficient operation of the control equipment.

The inspector should note the condition of paved and unpaved roads in the plant. At properly operated plants, fugitive dust is suppressed with water or chemical coatings. Larger quantities of spilled material on the roads are picked up and reused.

The inspector should note the condition of the plant's process monitoring equipment. Malfunctions can occur if it is not operating properly. Frequently, instruments are not properly maintained or used, or have not been calibrated recently. The mere presence of the instruments can give a plant a false sense of security until a serious problem of excess emissions results from lack of proper attention.

5.2 STARTUP AND SHUTDOWN PROBLEMS

For economic reasons, scheduled startup and shutdowns of cement kilns are kept to a minimum (usually about once every 100 days), but malfunctions in some part of the kiln system can result in unplanned shutdowns.[22] When a kiln has been shut down long enough to become cold, some type of preheating is necessary before restarting it. (Such preheating is not required to start up a kiln that has been down for only 3 or 4 hours because it will still be hot.) The preheating procedure normally requires 4 to 12 hours, but it can take as long as 48 hours. The firing temperature is gradually raised to prevent damage to the refractory material lining the kiln. The length of time required for this depends upon the age of the refractory. Newer refractory takes less time because it has a greater resistance to thermal stress.[6]

In coal-fired units equipped with ESP's, the heat-up procedure usually begins by firing with natural gas or fuel oil, rather than coal. During this initial period, the ESP is not energized because of the explosion hazard created by subjecting incomplete combustion products (CO) to sparking. Feed material is not introduced until the temperature of the kiln has stabilized and coal firing has begun and become stabilized. The ESP is energized only after the temperature stabilizes above the dewpoint and the CO levels are considered safe.

Heat-up time can be drastically reduced if the CO levels are monitored. One major ESP manufacturer indicates that the ESP can be partially energized throughout the entire heat-up procedure if CO and temperature are carefully monitored. Of course, should the monitor detect an explosion hazard or a critical temperature increase, the ESP must be de-energized.[22]

Excessive particulate and visible emissions usually occur during the startup of kilns equipped with ESP's, either because the units are not completely energized or not energized at all. In this situation, the ESP functions simply as a settling chamber. The use of fuel oil or natural gas as the preheating fuel will not only reduce the time needed for heat-up, but also reduce the atmospheric emissions.

During the preheating period, particulate emissions normally are not significant until rotation of the kiln begins and the feed material is introduced; however, preheating the kiln with coal while introducing feed material and operating a de-energized ESP will result in significant visible emissions.

Also important to the reduction of particulate and visible emissions during startup is the retention of heat within the kiln during the shutdown. This reduces the time needed for heat-up and thus, total emissions. Techniques for keeping dust within the kiln during these shutdowns are also important. Chains have been effective for this purpose. Pre-cleaners before the ESP (such as cyclones and multiple cyclones, which can operate throughout the entire preheat) also provide a good method for reducing emissions. They can remove 85 percent of the particulate that would normally be emitted if the ESP were not energized.[22]

The shutdown procedure can also increase particulate and visible emissions. One way to alleviate this problem is to operate the ESP until coal firing ceases or until the CO in the gas stream approaches the explosive level.[22]

Normally, kilns controlled by fabric filters do not have a problem with excessive emissions during startup and shutdown, as the collector continues to operate at full capacity during these periods. It should be noted, however, that a plant occasionally could choose to bypass the fabric filter during startup procedures to prevent the bags from being overloaded. When this occurs, excessive particulate emissions could result.

5.3 COMPLIANCE DETERMINATION AND EMISSION CALCULATIONS

The ultimate objective of portland cement plant inspections is to determine the compliance status of each of the sources. Federal, state, and local regulations set limits on atmospheric particulate emissions, usually according to process weight and opacity. Occasionally, plants also must meet production rate requirements.

A variety of methods can be used to determine compliance status. Table 9 provides a summary of methods that can be used for various processes. The greatest variety apply to the kiln. The inspector should record opacity readings according to the EPA Method 9 procedures (presented in Appendix D). These readings should not include the uncombined water (steam) fraction of the plume that frequently forms some distance from the stack outlet. Stack test data and transmissometer readings are based only on the primary formation within the stack. The inspector should also record opacity readings of fugitive emissions from the kiln and compare these readings with the applicable Federal, state, or local limit. The inspector's report should describe compliance of the kiln based on the opacity limit.

If opacity readings were obtained from the kiln during previous stack tests, opacity readings taken during this inspection provide an indication of control equipment operation and can be related to mass emissions. Conditions during the inspection must be identical to those during the stack test. The source must be operating at the same production level, gas flow rate must be the same, and the plume must be of the same diameter and observed from the same path, angle, and location. If the plant inspection opacity readings significantly exceed opacities recorded during the stack test, the mass emission rate is also likely to be higher. This is particularly critical as the measured mass emission rate approaches the limit of the emission regulation. This situation warrants further stack tests to determine compliance.

Material balance calculations for the kiln also can indicate whether emissions are approaching the allowable limits and a stack test is warranted. Figure 16 shows calculations for determining allowable and uncontrolled emissions, and then (by application of the Deutsch-Anderson equation for electrostatic precipitator efficiency) gives an estimate of controlled (actual)

TABLE 9. SUMMARY OF COMPLIANCE DETERMINATION METHODS FOR VARIOUS PROCESSES

	Kiln	Clinker cooler	Finish mill	Other
Opacity	X	X	X	X
Relate opacity to mass emission rate	X			
Material balance	X			
Change in operating parameters:				
Decreased ESP power	X	X		
Reduction in ESP fields	X	X		
Decreased gas stream moisture content		X		
Increased flow rate	X	X	X	
Increased insufflation	X			
Increased O_2 content	X			
Increased fuel consumption or production rate	X	X	X	
Deteriorated bags	X	X	X	

PARTICULATE EMISSION CALCULATION FOR KILN

Given: Wet process kiln producing 31 tons/h of clinker or 62,000 lb/h. Kiln feedrate (volume) at 190 gal/min and a slurry density of 106.9 lb/ft^3. Thus, the wet weight is 162,922 lb/h and dry solids are 106,876 lb/h because there is 34.4 percent moisture in the feed. Kiln controlled by ESP, designed for 250,000 acfm and 103,680 ft^2 of collecting area.

1. Allowable Emissions (AL)

Per NSPS: kiln is permitted 0.30 lb/ton of dry feed
Per Section 1.2 of this report: 1.6 tons dry feed per ton cement produced
Based on kiln producing 31 tons per hour

AL = 31 tons/h x 1.6 tons/ton x 0.3 lb/h
AL = 14.9 lb/h

2. a) Uncontrolled Emission Rate Per Mass Balance (UN)

Dry feed = 162,922 lb/h wet feed x (0.656) dry solids = 106,876 lb/h
CO_2 lost during calcining = dry feed (lb/h) x carbonate content (0.7275) x CO_2 loss to oxidation (0.44)

CO_2 lost = 106,876 (0.7275)(0.44)
= 34,211 lb/h

UN = dry feed - (CO_2 lost + clinker production rate)
= 106,876 lb/h - (34,211 lb/h + 62,000 lb/h)
= 10,665 lb/h

b) Uncontrolled Emissions Per AP-42 (UN')

AP-42 emission factor for uncontrolled wet process kilns is 228 lb/ton of clinker produced

UN' = 31 tons/h x 228 lb/ton
= 7068 lb/h

3. Actual Emissions Per Deutscn Anderson Equation for ESP Efficiency (AE)

a) Design efficiency for ESP per Deutsch-Anderson equation:

$$\eta = (1 - e^{-W\frac{A}{V}})100$$

where: η = collection efficiency, %
W = migration velocity, ft/s
A = electrode collecting area, ft^2
V = gas volume, acfs

Assume: Migration velocity of 0.34 ft/s per reference. (The McIlvaine Company, the Electrostatic Precipitator Manual, 1975, plus updates.)

Given: Electrode plate area is 103,680 ft^2 and gas flow is 250,000 acfm.
Specific collection area is 103,680 ÷ 250 = 414.7 $ft^2/10^3$ acfm

Calculation:

Convert V of 250,000 acfm to 4166.66 acfs by dividing by 60.

$$\eta = (1 - e^{-[0.34\ (\frac{103,680}{4166.66})]})100$$

$$\eta = (1 - e^{-8.46})100$$

$$\eta = (1 - \frac{1}{4723})100$$

$$\eta = (1 - 0.0002117)100$$

$$\eta = 99.98\%\ \text{collection efficiency}$$

Figure 16. Particulate emission estimate from portland cement kiln including comparison to AP-42 emission factor.

Figure 16 (continued)

b) Actual Efficiency for ESP Per Deutsch-Anderson equation

$$\eta = 100\ (1 - e^{-0.06\ K\ (\frac{P}{Q})})$$

where: K = constant value
P = corona power, watts
Q = flow, 10^3 ft^3/min

K is derived from previous stack tests where inlet and outlet values have been measured and an efficiency for the ESP determined at a given power input. The efficiency is substituted into the above formula along with the power input and solved for K.

In this case, we will assume an efficiency of 99 percent was measured in the test, where $p = 69{,}993$ watts and $Q = 170 \times 10^3$ acfm

Therefore $K = 0.186$ for this kiln

During the inspection, $p = 66{,}250$ watts and $Q = 125 \times 10^3$ ft^3/min

Therefore $\eta = (1 - e^{-0.06\ (0.186)\ \frac{66250}{125}})100$

$$\eta = (1 - e^{-5.9148})100$$

$$\eta = (1 - \frac{1}{370.48})100$$

$$\eta = (1 - 0.0026992)100$$

η = 99.73% collection efficiency

AE = UN x (100 - collection efficiency)/100

AE = 10,665 lb/h x 0.0027

AE = 28.80 lb/h or 0.54 lb/ton of dry feed emissions from the kiln. The Deutsch-Anderson equation is also presented in a manner that shows the ESP was designed for adequate control efficiency. Figure 16 also shows that the average emission factor from AP-42 for wet-process kilns is not accurate for this case. It may be a valid average for several kilns, but it does not represent an accurate emission value for an individual kiln.

The material balance calculation shown in Figure 16 for uncontrolled emissions is also valid if the kiln is controlled by a fabric filter. The control efficiency of the fabric filter (actual emissions) is based on the amount of dust removed from the collection hoppers of the device per unit of time. The plant routinely maintains data on the amount of material removed from the control device. Actual emission estimates from the ESP or fabric filter can then be compared with allowable emissions. If the estimated values exceed or approach allowable values, an emission test is warranted.

Other indicators of potential compliance problems are lower power levels to the ESP, increased fuel usage or production rates, reduction in ESP operating fields, increased exhaust flow rate, deterioration of fabric filter bags, increased insufflation, and increased oxygen to the control device. The combination of one or more of these parameters and an increase in opacity indicates that the mass emission rate may be higher than the values measured during the stack test. Stack tests for verification of compliance are needed.

Fewer clear-cut methods are available for determining the compliance status of clinker coolers. Regardless of the control method used by source, opacity readings generally are not a good indicator. For example, a significant increase in the mass emission rate is not alway detectable because of the size of the particles. If visible emissions are observed, however, an increase in mass emissions is likely, and stack tests are necessary for final compliance determination.

A better indicator of compliance for clinker coolers is to compare the operating parameters observed during the emission test with parameters recorded during this inspection. The nature of the clinker cooler prohibits material balance calculations. If the unit is controlled by an ESP, parameters that can contribute to higher mass emissions are lower power levels to the ESP, reduction in ESP operating fields, increased process rate, increased exhaust flow rate, and decreased moisture content in the gas stream. Moisture content of less than 4 to 10 percent causes resistivity problems and lowers collection efficiency. Depending on how closely the mass emission rate obtained from the stack tests compared with the standard and how widely operating parameters varied during the inspection, additional stack tests may be necessary to determine clinker cooler compliance.

If the clinker cooler is controlled by a fabric filter, pressure drop across the modules is not highly definitive. Several bags must be broken before the pressure drop decreases significantly. In general, the best parameter for determining compliance, short of stack testing, is to check the condition of the bags inside the fabric filter. Bag deterioration or excess dust buildup on the clean side of the bag may indicate an increase in mass emissions over those measured in the last stack test. A current stack test is warranted for definitive compliance determination.

The inspector can determine the compliance status of finish mills by comparing opacity readings made during the inspection with the opacity limit. Another method is to note if operating parameters differ from those recorded during previous compliance stack tests. These parameters include production level, exhaust flow rate, and the condition of the bags in the fabric filter. If there is significant variation in any one parameter or some variation in several parameters, additional stack tests are necessary for compliance determination.

As indicated in Section 4.5, fugitive emissions can present a problem in several areas of a plant, particularly around elevators, transporting areas, and storage piles. The inspector should take visible emission readings at these sources. The following calculation shows an emission estimate of uncontrolled fugitive emissions resulting from unloading, storing, and transfer of raw materials.

Emission factor (per Section 4.5) = 3.0 to 5.0 lb/ton
Assume 4.0 lb/ton of uncontrolled emissions.

Emission estimate based on 650,000 tons per year delivered:
650,000 tons/yr x 4.0 lb/ton x ton/2000 lb = 1300 tons/yr.

The final product of a compliance inspection is a report. Appendix F provides an example format for presenting the inspector's observations, calculations, assumptions and conclusions.

REFERENCES

1. Kirk-Othmer Encyclopedia of Chemical Terminology. Second completely revised edition. Volume 4. Cement. 1967.
2. Ackerson, Dennis H. Compilation of Air Pollution Emission Factors. Third Edition. U.S. Environmental Protection Agency Office of Air and Water Programs. Portland Cement Manufacturing.
3. Mineral Industry Surveys. U.S. Department of Interior. Bureau of Mines. November 12, 1981.
4. Midwest Research Institute. Particulate Pollutant System Study. Vol. III, Handbook of Emission Properties. Cement Manufacture U.S. Environmental Protection Agency. 1971.
5. Pit and Quarry Handbook and Buyers Guide 1975/1976. Pit and Quarry Publications, Inc. Chicago. 1976.
6. Kulujian, N. J. Inspection Manual for the Enforcement of New Source Performance Standards: Portland Cement Plants. PEDCo Environmental, Inc. Prepared for U.S. Environmental Protection Agency under Contract No. 68-02-1355, Task No. 4. January 1975.
7. U.S. Department of Interior. Mineral Facts and Problems. 1980 Edition. Cement. U.S. Bureau of Mines. 1980.
8. Hawks, R., and J. Richards. Field Inspection Report--Martin Marietta Cement Co., Martinsburg, West Virginia. Prepared for the U.S. Environmental Protection Agency by PEDCo Environmental, Inc., under Contract No. 68-02-4147. November 1980.
9. The McIlvaine Co. The Electrostatic Precipitator Manual. Northbrook, Illinois. December 1976.
10. PEDCo Environmental, Inc. Industrial Boiler Inspection Guide. Prepared for the U.S. Environmental Protection Agency under Contract No. 68-01-6310, Task No. 9. October 1981.

11. The McIlvaine Company. The Fabric Filter Manual. Northbrook, Illinois. 1975 plus updates.

12. Szabo, M., and J. Richards. Field Inspection Report--Columbia Cement Company, Bellingham, Washington. Prepared for the U.S. Environmental Protection Agency by PEDCo Environmental, Inc., under Contract No. 68-01-4147, Task No. 89. January 1980.

13. Szabo, M. F., and Y. M. Shah. Inspection Manual for Evaluation of Electrostatic Precipitator Performance. PEDCo Environmental, Inc. EPA-340/1-79-007. February 1979.

14. Oglesby, S., Jr., and G. B. Nichols. Electrostatic Precipitation In: Air Pollution, 3rd Edition, Vol. IV. Engineering Control of Air Pollution. Academic Press, New York. 1977.

15. PEDCo Environmental, Inc. Inspection and Operating and Maintenance Guidelines for Secondary Lead Smelters. (Draft) Prepared for the U.S. Environmental Protection Agency under Contract 68-03-2924. November 1981.

16. PEDCo Environmental, Inc. Inspection Report for Visit to Ideal Cement Co. Plant, Okay, Arkansas. Prepared for Region VI of U.S. Environmental Protection Agency. August 3, 1979.

17. PEDCo Environmental, Inc. Inspection Report for Visit to Arkansas Cement Corporation Plant, Foreman, Arkansas. Prepared for Region VI of U.S. Environmental Protection Agency. August 3, 1979.

18. Rexnord Corporation. Plan and Elevation drawings dated January 1979.

19. Jefferson County Air Quality Control Department. Stack test data for Universal Atlas Corp., Portland Cement Plant, Leed, Alabama. September 30, 1976.

20. PEDCo Environmental, Inc. Source Evaluation of Region IV Nonattainment Areas to Determine TSP Emission Reduction Capabilities. Prepared for the U.S. Environmental Protection Agency under Contract No. 68-02-2603, Task No. 2. June 1978.

21. Katari, V. Preparation of Process Description for Engineering Manual--Cement Plants. (Preliminary Draft.) Prepared by PEDCo Environmental, Inc., for the U.S. Environmental Protection Agency. December 1978.

22. Szabo, M., and Y. Shah. A Review of Particulate Emission Problems During Startup of Cement Kilns Equipped with Electrostatic Precipitators. Prepared by PEDCo Environmental, Inc., for U.S. Environmental Protection Agency. March 1979.

APPENDIX A

New Source Performance Standards for Portland Cement

Subpart F—Standards of Performance for Portland Cement Plants

§ 60.60 Applicability and designation of affected facility.

[42 FR 37936, July 25, 1977]

(a) The provisions of this subpart are applicable to the following affected facilities in portland cement plants: kiln, clinker cooler, raw mill system, finish mill system, raw mill dryer, raw material storage, clinker storage, finished product storage, conveyor transfer points, bagging and bulk loading and unloading systems.

(b) Any facility under paragraph (a) of this section that commences construction or modification after August 17, 1971, is subject to the requirements of this subpart.

§ 60.61 Definitions.

As used in this subpart, all terms not defined herein shall have the meaning given them in the Act and in Subpart A of this part.

(a) "Portland cement plant" means any facility manufacturing portland cement by either the wet or dry process.

§ 60.62 Standard for particulate matter.

(a) On and after the date on which the performance test required to be conducted by § 60.8 is completed, no owner or operator subject to the provisions of this subpart shall cause to be discharged into the atmosphere from any kiln any gases which:

(1) Contain particulate matter in excess of 0.15 kg per metric ton of feed (dry basis) to the kiln (0.30 lb per ton).

(2) Exhibit greater than 20 percent opacity.

[39 FR 39872, November 12, 1974]

(b) On and after the date on which the performance test required to be conducted by § 60.8 is completed, no owner or operator subject to the provisions of this subpart shall cause to be discharged into the atmosphere from any clinker cooler any gases which:

(1) Contain particulate matter in excess of 0.050 kg per metric ton of feed (dry basis) to the kiln (0.10 lb per ton).

(2) Exhibit 10 percent opacity, or greater.

(c) On and after the date on which the performance test required to be conducted by § 60.8 is completed, no owner or operator subject to the provisions of this subpart shall cause to be discharged into the atmosphere from any affected facility other than the kiln and clinker cooler any gases which exhibit 10 percent opacity, or greater.

(d) [Deleted].

[39 FR 20790, June 14, 1974; 40 FR 36250, October 6, 1975]

§ 60.63 Monitoring of operations.

(a) The owner or operator of any portland cement plant subject to the provisions of this part shall record the daily production rates and kiln feed rates.

[39 FR 20790, June 14, 1974]

(Sec. 114 of the Clean Air Act as amended (42 U.S.C. 7414).)

§ 60.64 Test methods and procedures.

(a) The reference methods in Appendix A to this part, except as provided for in § 60.8(b), shall be used to determine compliance with the standards prescribed in § 60.62 as follows:

(1) Method 5 for the concentration of particulate matter and the associated moisture content;

(2) Method 1 for sample and velocity traverses;

(3) Method 2 for velocity and volumetric flow rate; and

(4) Method 3 for gas analysis.

(b) For Method 5, the minimum sampling time and minimum sample volume for each run, except when process variables or other factors justify otherwise to the satisfaction of the Administrator, shall be as follows:

(1) 60 minutes and 0.85 dscm (30.0 dscf) for the kiln.

(2) 60 minutes and 1.15 dscm (40.6 dscf) for the clinker cooler.

(c) Total kiln feed rate (except fuels), expressed in metric tons per hour on a dry basis, shall be determined during each testing period by suitable methods; and shall be confirmed by a material balance over the production system.

(d) For each run, particulate matter emissions, expressed in g/metric ton of kiln feed, shall be determined by dividing the emission rate in g/hr by the kiln feed rate. The emission rate shall be determined by the equation, $g/hr = Q_s \times c$, where Q_s=volumetric flow rate of the total effluent in dscm/hr as determined in accordance with paragraph (a)(3) of this section, and c=particulate concentration in g/dscm as determined in accordance with paragraph (a)(1) of this section.

[39 FR 20790, June 14, 1974]

(Sec. 114 of the Clean Air Act as amended (42 U.S.C. 7414).)

APPENDIX B

1981 DIRECTORY OF PORTLAND CEMENT MANUFACTURING PLANTS

Company (Division)	Location	Process
Alpha Portland Industries, Inc. (Alpha Portland Cement Co.)	Lime Kiln, Maryland	Wet
Alpha Portland Industries, Inc. (Alpha Portland Cement Co.)	St. Louis, Missouri (to be closed end of 1981)	Wet
Alpha Portland Industries Inc. (Alpha Portland Cement Co.)	Cementon, New York	Wet
Alpha Portland Industries Inc. (Alpha Portland Cement Co.)	Orange, Texas	Wet
Arkansas Louisiana Gas Co. (Arkansas Cement Corp.)	Foreman, Arkansas	Wet
Ash Grove Cement Co.	Chanute, Kansas	Wet
Ash Grove Cement Co.	Louisville, Nebraska	Wet-Dry
Canada Cement Lafarge Ltd. (Citadel Cement Corp.)	Demopolis, Alabama	Dry
California Portland Cement Co.	Colton, California	Dry
California Portland Cement Co.	Mojave, California	Dry
California Portland Cement Co. (Arizona Portland Cement Co.)	Rillito, Arizona	Dry
Centex Corp. (Illinois Cement Co.)	LaSalle, Illinois	Dry

APPENDIX B (continued)

Company (Division)	Location	Process
Centex Corp. (Nevada Cement Co.)	Fernley, Nevada	Dry
Centex Corp. (Centex Cement Corp.)	Corpus Christi, Texas	Wet
Centex Corp. (Texas Cement Co.)	Buda, Texas	Dry
Crane Co. (Medusa Corp.)	Clinchfield, Georgia	Dry-Wet
Crane Co. (Medusa Cement Co.)	Charlevoix, Michigan	Wet
Crane Co. (Medusa Cement Co.)	Wampum, Pennsylvania	Dry
Crane Co. (Medusa Cement Co.)	York, Pennsylvania	Wet
Cyprus Mines Corp. (Cyprus Hawaiian Cement Corp.)	Barbers Point, Hawaii	Dry
Filtrol Corp. (Columbia Cement Corp.)	Zanesville, Ohio	Wet
Filtrol Corp. (Columbia Cement Corp.)	Bellingham, Washington	Wet
General Portland, Inc. (California Div.)	Los Robles, California	Dry
General Portland, Inc. (Florida Div.)	Miami, Florida	Wet
General Portland, Inc. (Florida Div.)	Tampa, Florida	Wet
General Portland, Inc. (Victor Div.)	Fredonia, Kansas	Wet
General Portland, Inc. (Peninsular Div.)	Paulding, Ohio	Wet
General Portland, Inc. (Whitehall Cement)	Cementon, Pennsylvania	Dry
General Portland, Inc. (Signal Mountain Div.)	Chattanooga, Tennessee	Wet

APPENDIX B (continued)

Company (Division)	Location	Process
General Portland, Inc. (Trinity North Div.)	Dallas, Texas	Wet
General Portland, Inc. (Trinity North Div.)	Fort Worth, Texas	Wet
General Portland, Inc. (Trinity North Div.)	New Braunfels, Texas	Dry
Genstar Corp. (Genstar Cement and Lime Co.)	Redding, California	Dry
Genstar Corp. (Cala Veras Cement Div.)	San Andreas, California	Wet
Giant Portland and Masonry Cement Co.	Harleyville, South Carolina	Wet
Gifford-Hill and Co., Inc.	Harleyville, South Carolina	Dry
Gifford-Hill and Co., Inc. (Phoenix Cement Co.)	Clarkdale, Arizona	Dry
Gifford-Hill and Co., Inc. (Riverside Cement Co.)	Crestmore, California	Dry
Gifford-Hill and Co., Inc. (Riverside Cement Co.)	Oro Grande, California	Dry
Gifford-Hill and Co., Inc. (Peerless Cement Co.)	Detroit, Michigan	Wet
Gifford-Hill and Co., Inc. (Gifford-Hill Portland Cement Co.)	Midlothian, Texas	Wet
Gulf & Western Industries, Inc. (Marquette Co.)	Rockmart, Georgia	Dry
Gulf & Western Industries, Inc. (Marquette Co.)	Oglesby, Illinois	Dry
Gulf & Western Industries, Inc. (Marquette Co.)	Hagerstown, Maryland	Dry
Gulf & Western Industries, Inc. (Marquette Co.)	Brandon, Mississippi	Wet

APPENDIX B (continued)

Company (Division)	Location	Process
Gulf & Western Industries, Inc. (Marquette Co.)	Cape Girardeau, Missouri	Wet
Gulf & Western Industries, (Marquette Co.)	Catskill, New York	Wet
Gulf & Western Industries, Inc. (Marquette Co.)	Superior, Ohio	Dry
Gulf & Western Industries, Inc. (Marquette Co.)	Pittsburgh, Pennsylvania	Wet
Heidelberger Zement AG (Lehigh Portland Cement Co.)	Leeds, Alabama	Dry
Heidelberger Zement AG (Lehigh Portland Cement Co.)	Buffington, Indiana	Grinding
Heidelberger Zement AG (Lehigh Portland Cement Co.)	Mitchell, Indiana	Dry
Heidelberger Zement AG (Lehigh Portland Cement Co.)	Mason City, Iowa	Dry
Heidelberger Zement AG (Lehigh Portland Cement Co.)	Independence, Kansas	Dry
Heidelberger Zement AG (Lehigh Portland Cement Co.)	Union Bridge, Maryland	Dry
Heidelberger Zement AG (Lehigh Portland Cement Co.)	Hannibal, Missouri	Wet
Heidelberger Zement AG (Lehigh Portland Cement Co.)	Alsen, New York	Dry
Heidelberger Zement AG (Lehigh Portland Cement Co.)	Northhampton, Pennsylvania	Wet
Heidelberger Zement AG (Lehigh Portland Cement Co.)	Waco, Texas	Wet-Dry
Heidelberger Zement AG (Lehigh Portland Cement Co.)	Metaline Falls, Washington	Dry
Heidelberger Zement AG (Lehigh Portland Cement Co.)	Milwaukee, Wisconsin	Grinding

APPENDIX B (continued)

Company (Division)	Location	Process
H.B. Zachry Co. (Capitol Aggregates, Inc.)	San Antonio, Texas	Wet
H.K. Porter Co., Inc. (Missouri Portland Cement Co.)	Joppa, Illinois	Dry
H.K. Porter Co., Inc. (Missouri Portland Cement Co.)	St. Louis, Missouri	Wet
H.K. Porter Co., Inc. (Missouri Portland Cement (Co.)	Sugar Creek, Missouri	Dry
Holderbank Group (Dundee Cement Co.)	Dundee, Michigan	Wet
Holderbank Group (Dundee Cement Co.)	Clarksville, Missouri	Wet
Holderbank Group (Santee Portland Cement Corp., Dundee Cement Co.)	Hollyhill, South Carolina	Wet
Ideal Basic Industries, Inc. (Cement Div.)	Theodore, Alabama	Dry
Ideal Basic Industries, Inc. (Cement Div.)	Okay, Arkansas	Wet
Ideal Basic Industries, Inc. (Cement Div.)	Boettcher, Colorado	Dry
Ideal Basic Industries, Inc. (Cement Div.)	Portland, Colorado	Wet
Ideal Basic Industries, Inc. (Cement Div.)	Trident, Montana	Wet
Ideal Basic Industries, Inc. (Cement Div.)	Superior, Nebraska	Wet
Ideal Basic Industries, Inc. (Cement Div.)	Tijevas, New Mexico	Dry
Ideal Basic Industries, Inc. (Cement Div.)	Castle Hayne, North Carolina	Wet

APPENDIX B (continued)

Company (Division)	Location	Process
Ideal Basic Industries, Inc. (Cement Div.)	Ada, Oklahoma	Wet
Ideal Basic Industries, Inc. (Cement Div.)	Knoxville, Tennessee	Dry
Ideal Basic Industries, Inc. (Cement Div.)	Galena Park, Texas	Wet
Ideal Basic Industries, Inc. (Cement Div.)	Devils Slide, Utah	Wet
Ideal Basic Industries, Inc. (Cement Div.)	Seattle, Washington	Wet
Instituto Finanziano Industrial (Hercules Cement Co.)	Stockertown, Pennsylvania	Dry
Instituto Finanziano Industrial (River Cement Co.)	Festus, Missouri	Dry
Kaiser Cement Corp.	Lucerne Valley, California	Wet
Kaiser Cement Corp.	Permanente, California	Wet
Kaiser Cement Corp.	Waianae, Hawaii	Wet
Kaiser Cement Corp.	Montana City, Montana	Wet
Kaiser Cement Corp.	San Antonio, Texas	Dry
Keystone Portland Cement Co.	Bath, Pennsylvania	Wet
Lake Ontario Cement Ltd. (Aetna Cement Corp.)	Essexville, Michigan	Grinding
Lone Star Industries, Inc. (Cement and Construction Mat. Group)	Santa Cruz, California	Dry
Lone Star Industries, Inc. (Cement and Construction Mat. Group)	Dixon, Illinois	Dry
Lone Star Industries, Inc. (Cement and Construction Mat. Group)	Greencastle, Indiana	Wet
Lone Star Industries, Inc. (Cement and Construction Mat. Group)	Bonner Springs, Kansas	Wet

APPENDIX B (continued)

Company (Division)	Location	Process
Lone Star Industries, Inc. (Cement and Construction Mat. Group)	New Orleans, Louisiana	Wet
Lone Star Industries, Inc. (Cement and Construction Mat. Group)	Pryor, Oklahoma	Dry
Lone Star Industries, Inc. (Cement and Construction Mat. Group)	Nazareth, Pennsylvania	Dry
Lone Star Industries, Inc. (Cement and Construction Mat. Group)	Houston, Texas	Wet
Lone Star Industries, Inc. (Cement and Construction Mat. Group)	Maryneal, Texas	Dry
Lone Star Industries, Inc. (Cement and Construction Mat. Group)	Roanoke, Virginia	Dry
Lone Star Industries, Inc. (Cement and Construction Mat. Group)	Seattle, Washington	Wet
Lone Star Industries, Inc. (Portland Cement Co. of Utah)	Salt Lake City, Utah	Wet
Lone Star Industries, Inc. (Lonestar Florida Pennsuco, Inc.)	Miami, Florida	Wet
Louisville Cement Co.	Logansport, Indiana	Wet
Louisville Cement Co.	Speed, Indiana	Dry
Louisville Cement Co. (Bessemer Cement Co.)	Bessemer, Pennsylvania	Wet
Marmac Corp. (Gulf Coast Portland Cement Co.)	Houston, Texas	Wet
Martin Marietta Corp. (Martin Marietta Cement Div.)	Calera, Alabama	Dry

APPENDIX B (continued)

Company (Division)	Location	Process
Martin Marietta Corp. (Martin Marietta Cement Div.)	Lyons, Colorado	Dry
Martin Marietta Corp. (Martin Marietta Cement Div.)	Atlanta, Georgia	Dry
Martin Marietta Corp. (Martin Marietta Cement Div.)	Davenport, Iowa	Wet
Martin Marietta Corp. (Martin Marietta Cement Div.)	West Des Moines, Iowa	Wet
Martin Marietta Corp. (Martin Marietta Cement Div.)	Thomaston, Maine	Wet
Martin Marietta Corp. (Martin Marietta Cement Div.)	Tulsa, Oklahoma	Dry
Martin Marietta Corp. (Martin Marietta Cement Div.)	Northhampton, Pennsylvania	Dry
Martin Marietta Corp. (Martin Marietta Cement Div.)	Martinsburg, West Virginia	Wet
The Monarch Cement Co.	Des Moines, Iowa	Wet
The Monarch Cement Co.	Humboldt, Kansas	Dry
Monolith Portland Cement Co.	Monolith, California	Wet
Monolith Portland Cement Co.	Laramie, Wyoming	Wet
Moore McCormack Cement, Inc. (Florida Mining & Materials Corp.)	Brooksville, Florida	Dry
Moore McCormack Cement, Inc. (Kosmos Cement Co., Inc.)	Kosmosdale, Kentucky	Dry
Moore McCormack Cement, Inc. (Glens Falls Portland Cement Co., Inc.)	Glens Falls, New York	Dry

APPENDIX B (continued)

Company (Division)	Location	Process
Moore McCormack Cement, Inc. (Glens Falls Portland Cement Co., Inc.)	Howes Cave, New York	Grinding
Moore McCormack Cement, Inc. (Dixie Cement Co., Inc.)	Kingsport, Tennessee	Wet
Moore McCormack Cement, Inc. (Dixie Cement Co., Inc.)	Richard City, Tennessee	Wet
National Gypsum Co. (Allentown Cement Div.)	Evansville, Pennsylvania	Dry
National Gypsum Co. (Huron Cement Div.)	Alpena, Michigan	Dry
National Gypsum Co. (Huron Cement Div.)	Superior, Wisconsin	Grinding
National Portland Cement Co. of Florida, Inc.	Bradenton, Florida	Grinding
Newmont Mining Corop. (Atlantic Cement Co., Inc.)	Ravena, New York	Wet
Northwestern States Portland Cement, Co.	Mason City, Iowa	Dry
Oregon Portland Cement Co.	Durkee, Oregon	Dry-Wet
Oregon Portland Cement Co.	Lake Oswego, Oregon	Wet
Oregon Portland Cement Co. (Idaho Portland Cement Div.)	Inkom, Idaho	Wet
Penn-West Cement Co., Inc.	West Winfield, Pennsylvania	Wet
Presa S.P.A. Cementeria di Robilante (Alamo Cement Co.) (joint venture)	Cementville, Texas	Wet
Puerto Rican Cement Co., Inc.	Ponce, Puerto Rico	Wet
Rinker Materials Corp. (Rinker Portland Cement Corp.)	Miami, Florida	Wet
San Juan Cement Co., Inc.	Dorado, Puerto Rico	Wet

APPENDIX B (continued)

Company (Division)	Location	Process
Société Anonyme des Ciments Vicat (National Cement Co., Inc.)	Ragland, Alabama	Dry
Société des Ciments Francais (Coplay Cement Co.)	Coplay, Pennsylvania	Grinding
Société des Ciments Francais (Coplay Cement Co.)	Nazareth, Pennsylvania	Dry
Société des climents Francais (Coplay Cement Co.)	Nazareth, Pennsylvania	Grinding
South Dakota Cement Plant Commission	Rapid City, South Dakota	Wet-Dry
Southdown, Inc. (Southwestern Portland Cement Co.)	Victorville, California	Dry-Wet
Southdown, Inc. (Southwestern Portland Cement Co.)	Fairborn, Ohio	Dry-Wet
Southdown, Inc. (Southwestern Portland Cement Co.)	Amarillo, Texas	Wet
Southdown, Inc. (Southwestern Portland Cement Co.)	El Paso, Texas	Dry
Southdown, Inc. (Southwestern Portland Cement Co.)	Odessa, Texas	Dry
Standard Machine and Equipment Co. (SME Cement, Inc.)	Middlebranch, Ohio	Dry
Standard Machine and Equip- Co. (SME Cement, Inc.)	Sylvania, Ohio	Dry
St. Mary's Cement Ltd (Wyandotte Cement Inc.)	Wyandotte, Michigan	Grinding
Texas Industries, Inc.	Midlothian, Texas	Wet
Texas Industries, Inc. (TXI Cement Co.)	New Braufels, Texas	Dry

APPENDIX B (continued)

Company (Division)	Location	Process
Texas Industries, Inc. (United Cement Co.)	Artesia, Mississippi	Wet

APPENDIX C

SAMPLE FORMS

PRE-INSPECTION ABATEMENT ACTIVITIES CHECKLIST

Name of company: ______________________________

Address: ______________________________

Responsible person: ______________________________

Previous Inspection:

Date: ______________
Findings: ______________________________
Process rate: ______________ tons/day Kiln O_2: __________ %
Gas temperature: __________ °F Gas flow rate: __________ acfm
Emission control equipment parameters: ______________
____

Stack Test:

Testing company: ______________________________
Date of test: ______________________________
Results (obtain copy if possible): ______________
Visible emissions observations: ______________
Compliance status: ______________________________
Action taken: ______________________________
Process rate: ______________ tons/day Kiln O_2 __________ %
Gas temperature: __________ °F Gas flow rate: __________ acfm
Gas moisture content: ______________________________ %
Emission control equipment parameters: ______________

Visible Emission Observations (other than above):

Date: ______________
Average readings: ______________________________

Complaints:

Dates, nature, and findings: ______________
____
____

Malfunctions:

Dates, nature, duration, and action taken: ______________
____
____
____

Compliance Schedule:

____

CHECKLIST FOR PROCESS DATA

Kiln:

Dimensions: ______________________________________ ft
Chains: _____ Yes _____ No
Process: _____ Wet _____ Dry
Slurry:
Feed rate _______ gal/min Moisture _____ % Carbonate ______ %
Type cement produced: ________________
Dry solids __________ tons/h
Fuel:
Type: ________
Quality: ______ % ash; _____ % sulfur; ______ Btu/lb heat content
Firing rate _____ tons/h
Alkali content of feed: ______________ %
Volume of clinker production: __________ tons/h
Dust reentrainment:
Volume _________ lb/h Source __________
Flue gas:
Volume _________ acfm
Temperature _________ °F
% oxygen ___________

Clinker Cooler:

Type: ______________
Flue gas:
Volume ___________________ acfm
Temperature ________________ °F
Clinker cooling rate _______ tons/h

Finishing Mill:

Number: ____________
Volume handled by each: _________ tons/h
Type: ________________________
Flue gas:
Volume _________ acfm
Temperature _____ °F

Crusher

Number: __________
Volume handled by each: _________ tons/h
Type: ________________________
Flue gas:
Volume _________ acfm
Temperature _________ °F

CHECKLIST FOR CONTROL EQUIPMENT

Kiln:

Fabric filter: ____ Yes ____ No
Cloth ____________________
Area ____________________ ft^2
Air-to-cloth ratio ____________ $acfm/ft^2$
Pressure drop ______________ in. H_2O
Collection efficiency __________ %

Electrostatic precipitator: ____ Yes ____ No
Total plate area ______________ ft^2
Wire length ______________ ft
Specific collection area ________ ft^2/ 1000 acfm
Collection efficiency __________ %

Fields ______________
Chambers ______________
Superficial velocity ________ ft/s
Number T/R sets ____________
Water rate ______________ gal/min

Precleaner: Type ______________
Description ______________

Clinker Cooler:

Fabric filter: ____ Yes ____ No
Cloth type ______________
Area ______________
Air-to-cloth ratio ____________ acfm/ ft^2
Pressure drop ______________ in. H_2O
Collection efficiency __________ %

Type of bag cleaning:
____ Shaker
____ Pulse jet
____ Reverse air

Multiple cyclone: ____ Yes ____ No
Number of tubes ________
Tube diameter __________ in.
Pressure drop __________ in. H_2O
Collection efficiency __________ %

Electrostatic precipitator: ____ Yes ____ No
Plate area ______________ ft^2
Wire length ______________ ft
Specific collection area ________ ft^2/ 1000 acfm
Collection efficiency __________ %

Fields ______________
Chambers ______________
Superficial velocity ________ ft/s
Number T/R sets ____________
Water rate ______________ gal/min

Gravel bed: ____ Yes ____ No
Pressure drop ______________ in. H_2O
Number of compartments __________
Collection efficiency __________ %

Finishing Mill:

Fabric filter: ____ Yes ____ No
Cloth type ______________
Area ______________ ft^2
Air-to-cloth ratio ____________ acfm/ ft^2
Pressure drop ______________ in. H_2O
Collection efficiency __________ %

Type of bag cleaning:
____ Shaker
____ Pulse jet
____ Reverse air

APPENDIX D

Method 9 - Visible Emission Evaluation

METHOD 9—VISUAL DETERMINATION OF THE OPACITY OF EMISSIONS FROM STATIONARY SOURCES

Many stationary sources discharge visible emissions into the atmosphere; these emissions are usually in the shape of a plume. This method involves the determination of plume opacity by qualified observers. The method includes procedures for the training and certification of observers, and procedures to be used in the field for determination of plume opacity. The appearance of a plume as viewed by an observer depends upon a number of variables, some of which may be controllable and some of which may not be controllable in the field. Variables which can be controlled to an extent to which they no longer exert a significant influence upon plume appearance include: Angle of the observer with respect to the plume; angle of the observer with respect to the sun; point of observation of attached and detached steam plume; and angle of the observer with respect to a plume emitted from a rectangular stack with a large length to width ratio. The method includes specific criteria applicable to these variables.

Other variables which may not be controllable in the field are luminescence and color contrast between the plume and the background against which the plume is viewed. These variables exert an influence upon the appearance of a plume as viewed by an observer, and can affect the ability of the observer to accurately assign opacity values to the observed plume. Studies of the theory of plume opacity and field studies have demonstrated that a plume is most visible and presents the greatest apparent opacity when viewed against a contrasting background. It follows from this, and is confirmed by field trials, that the opacity of a plume, viewed under conditions where a contrasting background is present can be assigned with the greatest degree of accuracy. However, the potential for a positive error is also the greatest when a plume is viewed under such contrasting conditions. Under conditions presenting a less contrasting background, the apparent opacity of a plume is less and approaches zero as the color and luminescence contrast decrease toward zero. As a result, significant negative bias and negative errors can be made when a plume is viewed under less contrasting conditions. A negative bias decreases rather than increases the possibility that a plant operator will be cited for a violation of opacity standards due to observer error.

Studies have been undertaken to determine the magnitude of positive errors which can be made by qualified observers while reading plumes under contrasting conditions and using the procedures set forth in this method. The results of these studies (field trials) which involve a total of 769 sets of 25 readings each are as follows:

(1) For black plumes (133 sets at a smoke generator), 100 percent of the sets were read with a positive error[1] of less than 7.5 percent opacity; 99 percent were read with a positive error of less than 5 percent opacity.

(2) For white plumes (170 sets at a smoke generator, 168 sets at a coal-fired power plant, 298 sets at a sulfuric acid plant), 99 percent of the sets were read with a positive error of less than 7.5 percent opacity; 95 percent were read with a positive error of less than 5 percent opacity.

The positive observational error associated with an average of twenty-five readings is therefore established. The accuracy of the method must be taken into account when determining possible violations of applicable opacity standards.

1. *Principle and applicability.*

1.1 Principle. The opacity of emissions from stationary sources is determined visually by a qualified observer.

1.2 Applicability. This method is applicable for the determination of the opacity of emissions from stationary sources pursuant to § 60.11(b) and for qualifying observers for visually determining opacity of emissions.

2. *Procedures.* The observer qualified in accordance with paragraph 3 of this method shall use the following procedures for visually determining the opacity of emissions:

2.1 Position. The qualified observer shall stand at a distance sufficient to provide a clear view of the emissions with the sun oriented in the 140° sector to his back. Consistent with maintaining the above requirement, the observer shall, as much as possible, make his observations from a position such that his line of vision is approximately perpendicular to the plume direction, and when observing opacity of emissions from rectangular outlets (e.g. roof monitors, open baghouses, noncircular stacks), approximately perpendicular to the longer axis of the outlet. The observer's line of sight should not include more than one plume at a time when multiple stacks are involved, and in any case the observer should make his observations with his line of sight perpendicular to the longer axis of such a set of multiple stacks (e.g. stub stacks on baghouses).

2.2 Field records. The observer shall record the name of the plant, emission location, type facility, observer's name and affiliation, and the date on a field data sheet (Figure 9-1). The time, estimated distance to the emission location, approximate wind direction, estimated wind speed, description of the sky condition (presence and color of clouds), and plume background are recorded on a field data sheet at the time opacity readings are initiated and completed.

---

[1] For a set, positive error=average opacity determined by observers' 25 observations—average opacity determined from transmissometer's 25 recordings.

2.3 Observations. Opacity observation. shall be made at the point of greatest opacity in that portion of the plume where condensed water vapor is not present. The observer shall not look continuously at the plume, but instead shall observe the plume momentarily at 15-second intervals.

2.3.1 Attached steam plumes. When condensed water vapor is present within the plume as it emerges from the emission outlet, opacity observations shall be made beyond the point in the plume at which condensed water vapor is no longer visible. The observer shall record the approximate distance from the emission outlet to the point in the plume at which the observations are made.

2.3.2 Detached steam plume. When water vapor in the plume condenses and becomes visible at a distinct distance from the emission outlet, the opacity of emissions should be evaluated at the emission outlet prior to the condensation of water vapor and the formation of the steam plume.

2.4 Recording observations. Opacity observations shall be recorded to the nearest 5 percent at 15-second intervals on an observational record sheet. (See Figure 9-2 for an example.) A minimum of 24 observations shall be recorded. Each momentary observation recorded shall be deemed to represent the average opacity of emissions for a 15-second period.

2.5 Data Reduction. Opacity shall be determined as an average of 24 consecutive observations recorded at 15-second intervals. Divide the observations recorded on the record sheet into sets of 24 consecutive observations. A set is composed of any 24 consecutive observations. Sets need not be consecutive in time and in no case shall two sets overlap. For each set of 24 observations, calculate the average by summing the opacity of the 24 observations and dividing this sum by 24. If an applicable standard specifies an averaging time requiring more than 24 observations, calculate the average for all observations made during the specified time period. Record the average opacity on a record sheet. (See Figure 9-1 for an example.)

3. *Qualifications and testing.*

3.1 Certification requirements. To receive certification as a qualified observer, a candidate must be tested and demonstrate the ability to assign opacity readings in 5 percent increments to 25 different black plumes and 25 different white plumes, with an error not to exceed 15 percent opacity on any one reading and an average error not to exceed 7.5 percent opacity in each category. Candidates shall be tested according to the procedures described in paragraph 3.2. Smoke generators used pursuant to paragraph 3.2 shall be equipped with a smoke meter which meets the requirements of paragraph 3.3.

The certification shall be valid for a period of 6 months, at which time the qualification procedure must be repeated by any observer in order to retain certification.

3.2 Certification procedure. The certification test consists of showing the candidate a complete run of 50 plumes—25 black plumes and 25 white plumes—generated by a smoke generator. Plumes within each set of 25 black and 25 white runs shall be presented in random order. The candidate assigns an opacity value to each plume and records his observation on a suitable form. At the completion of each run of 50 readings, the score of the candidate is determined. If a candidate fails to qualify, the complete run of 50 readings must be repeated in any retest. The smoke test may be administered as part of a smoke school or training program, and may be preceded by training or familiarization runs of the smoke generator during which candidates are shown black and white plumes of known opacity.

3.3 Smoke generator specifications. Any smoke generator used for the purposes of paragraph 3.2 shall be equipped with a smoke meter installed to measure opacity across the diameter of the smoke generator stack. The smoke meter output shall display in-stack opacity based upon a pathlength equal to the stack exit diameter, on a full 0 to 100 percent chart recorder scale. The smoke meter optical design and performance shall meet the specifications shown in Table 9-1. The smoke meter shall be calibrated as prescribed in paragraph 3.3.1 prior to the conduct of each smoke reading test. At the completion of each test, the zero and span drift shall be checked and if the drift exceeds ±1 percent opacity, the condition shall be corrected prior to conducting any subsequent test runs. The smoke meter shall be demonstrated, at the time of installation, to meet the specifications listed in Table 9-1. This demonstration shall be repeated following any subsequent repair or replacement of the photocell or associated electronic circuitry including the chart recorder or output meter, or every 6 months, whichever occurs first.

TABLE 9-1—SMOKE METER DESIGN AND PERFORMANCE SPECIFICATIONS

Parameter:	*Specification*
a. Light source	Incandescent lamp operated at nominal rated voltage.
b. Spectral response of photocell.	Photopic (daylight spectral response of the human eye—reference 4.3).
c. Angle of view	15° maximum total angle.
d. Angle of projection.	15° maximum total angle.
e. Calibration error.	±3% opacity, maximum.
f. Zero and span drift.	±1% opacity, 30 minutes.
g. Response time	≤5 seconds.

3.3.1 Calibration. The smoke meter is calibrated after allowing a minimum of 30 minutes warmup by alternately producing simulated opacity of 0 percent and 100 percent. When stable response at 0 percent or 100 percent is noted, the smoke meter is adjusted to produce an output of 0 percent or 100 percent, as appropriate. This calibration shall be repeated until stable 0 percent and 100 percent readings are produced without adjustment. Simulated 0 percent and 100 percent opacity values may be produced by alternately switching the power to the light source on and off while the smoke generator is not producing smoke.

3.3.2 Smoke meter evaluation. The smoke meter design and performance are to be evaluated as follows:

3.3.2.1 Light source. Verify from manufacturer's data and from voltage measurements made at the lamp, as installed, that the lamp is operated within ±5 percent of the nominal rated voltage.

3.3.2.2 Spectral response of photocell. Verify from manufacturer's data that the photocell has a photopic response; i.e., the spectral sensitivity of the cell shall closely approximate the standard spectral-luminosity curve for photopic vision which is referenced in (b) of Table 9-1.

3.3.2.3 Angle of view. Check construction geometry to ensure that the total angle of view of the smoke plume, as seen by the photocell, does not exceed 15°. The total angle of view may be calculated from: $\theta=2\tan^{-1} d/2L$, where θ=total angle of view; d=the sum of the photocell diameter+the diameter of the limiting aperture; and L=the distance from the photocell to the limiting aperture. The limiting aperture is the point in the path between the photocell and the smoke plume where the angle of view is most restricted. In smoke generator smoke meters this is normally an orifice plate.

3.3.2.4 Angle of projection. Check construction geometry to ensure that the total angle of projection of the lamp on the smoke plume does not exceed 15°. The total angle of projection may be calculated from: $\theta=2\tan^{-1} d/2L$, where θ= total angle of projection; d= the sum of the length of the lamp filament + the diameter of the limiting aperture; and L= the distance from the lamp to the limiting aperture.

3.3.2.5 Calibration error. Using neutral-density filters of known opacity, check the error between the actual response and the theoretical linear response of the smoke meter. This check is accomplished by first calibrating the smoke meter according to 3.3.1 and then inserting a series of three neutral-density filters of nominal opacity of 20, 50, and 75 percent in the smoke meter pathlength. Filters calibarted within ±2 percent shall be used. Care should be taken when inserting the filters to prevent stray light from affecting the meter. Make a total of five nonconsecutive readings for each filter. The maximum error on any one reading shall be 3 percent opacity.

3.3.2.6 Zero and span drift. Determine the zero and span drift by calibrating and operating the smoke generator in a normal manner over a 1-hour period. The drift is measured by checking the zero and span at the end of this period.

3.3.2.7 Response time. Determine the response time by producng the series of five simulated 0 percent and 100 percent opacity values and observing the time required to reach stable response. Opacity values of 0 percent and 100 percent may be simulated by alternately switching the power to the light source off and on while the smoke generator is not operating.

4. *References.*

4.1 Air Pollution Control District Rules and Regulations, Los Angeles County Air Pollution Control District, Regulation IV, Prohibitions, Rule 50.

4.2 Weisburd, Melvin I., Field Operations and Enforcement Manual for Air, U.S. Environmental Protection Agency, Research Triangle Park, N.C., APTD-1100, August 1972. pp. 4.1-4.36..

4.3 Condon, E. U., and Odishaw, H., Handbook of Physics, McGraw-Hill Co., N.Y., N.Y., 1958, Table 3.1, p. 6-52.

FIGURE 9-1
RECORD OF VISUAL DETERMINATION OF OPACITY

PAGE___of___

COMPANY________________
LOCATION________________
TEST NUMBER________________
DATE________________
TYPE FACILITY________________
CONTROL DEVICE________________

HOURS OF OBSERVATION________________
OBSERVER________________
OBSERVER CERTIFICATION DATE________________
OBSERVER AFFILIATION________________
POINT OF EMISSIONS________________
HEIGHT OF DISCHARGE POINT________________

	Initial			Final
CLOCK TIME				
OBSERVER LOCATION Distance to Discharge				
Direction from Discharge				
Height of Observation Point				
BACKGROUND DESCRIPTION				
WEATHER CONDITIONS Wind Direction				
Wind Speed				
Ambient Temperature				
SKY CONDITIONS (clear, overcast, % clouds, etc.)				
PLUME DESCRIPTION Color				
Distance Visible				
OTHER INFORMATION				

SUMMARY OF AVERAGE OPACITY

Set Number	Time	Opacity	
	Start--End	Sum	Average

Readings ranged from ____ to ____ % opacity

The source was/was not in compliance with ____ at the time evaluation was made.

FIGURE 9-2 OBSERVATION RECORD

PAGE ___ OF ___

COMPANY ____________
LOCATION ____________
TEST NUMBER ____________
DATE ____________

OBSERVER ____________
TYPE FACILITY ____________
POINT OF EMISSIONS ____________

		Seconds				STEAM PLUME (check if applicable)		
Hr.	Min.	0	15	30	45	Attached	Detached	COMMENTS
	0							
	1							
	2							
	3							
	4							
	5							
	6							
	7							
	8							
	9							
	10							
	11							
	12							
	13							
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	15							
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	17							
	18							
	19							
	20							
	21							
	22							
	23							
	24							
	25							
	26							
	27							
	28							
	29							

FIGURE 9-2 OBSERVATION RECORD
(Continued)

PAGE ___ OF ___

COMPANY ____________
LOCATION ____________
TEST NUMBER ____________
DATE ____________

OBSERVER ____________
TYPE FACILITY ____________
POINT OF EMISSIONS ____________

		Seconds				STEAM PLUME (check if applicable)		
Hr.	Min.	0	15	30	45	Attached	Detached	COMMENTS
	30							
	31							
	32							
	33							
	34							
	35							
	36							
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	38							
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APPENDIX E

DESCRIPTION OF ATMOSPHERIC EMISSION CONTROL SYSTEMS

I. ELECTROSTATIC PRECIPITATORS

The mechanism by which an electrostatic precipitator (ESP) removes particulate matter from a gas stream consists of three steps: 1) the suspended particles in the gas stream are given a charge, 2) the electrically charged particles are attracted to an oppositely charged surface, and 3) the collected particles are discharged from the surface and fall into a hopper.

The electrostatic precipitator (as shown in Figure E-1) consists of a shell of metal, tile, or some similar material in which are suspended grounded steel plates, which act as collecting electrodes, and negatively charged metal wires or rods, which act as discharge electrodes.[1] The wires are suspended between the plates, and weights are attached to them to keep them taut.

A high-voltage transformer-rectifier (TR) system provides the wires with a high-voltage direct current (dc) power source. The transformer steps up the alternating current (ac) supply generated at the plant to the desired value before the rectifier converts it to dc voltage. Each T-R set forms one field; thus the unit pictured has three fields (i.e., three T-R sets). Gas flow uniformity across the precipitator cross section is regulated by the use of perforated distribution plates in the gas inlet to the precipitator. Particles are removed from the collecting electrodes by periodic rapping or vibration of the plates. The plate cleaning mechanism is activated either pneumatically or electrically.[2]

The design of an electrostatic precipitator is based on a specific collection area (SCA) measured in terms of collecting

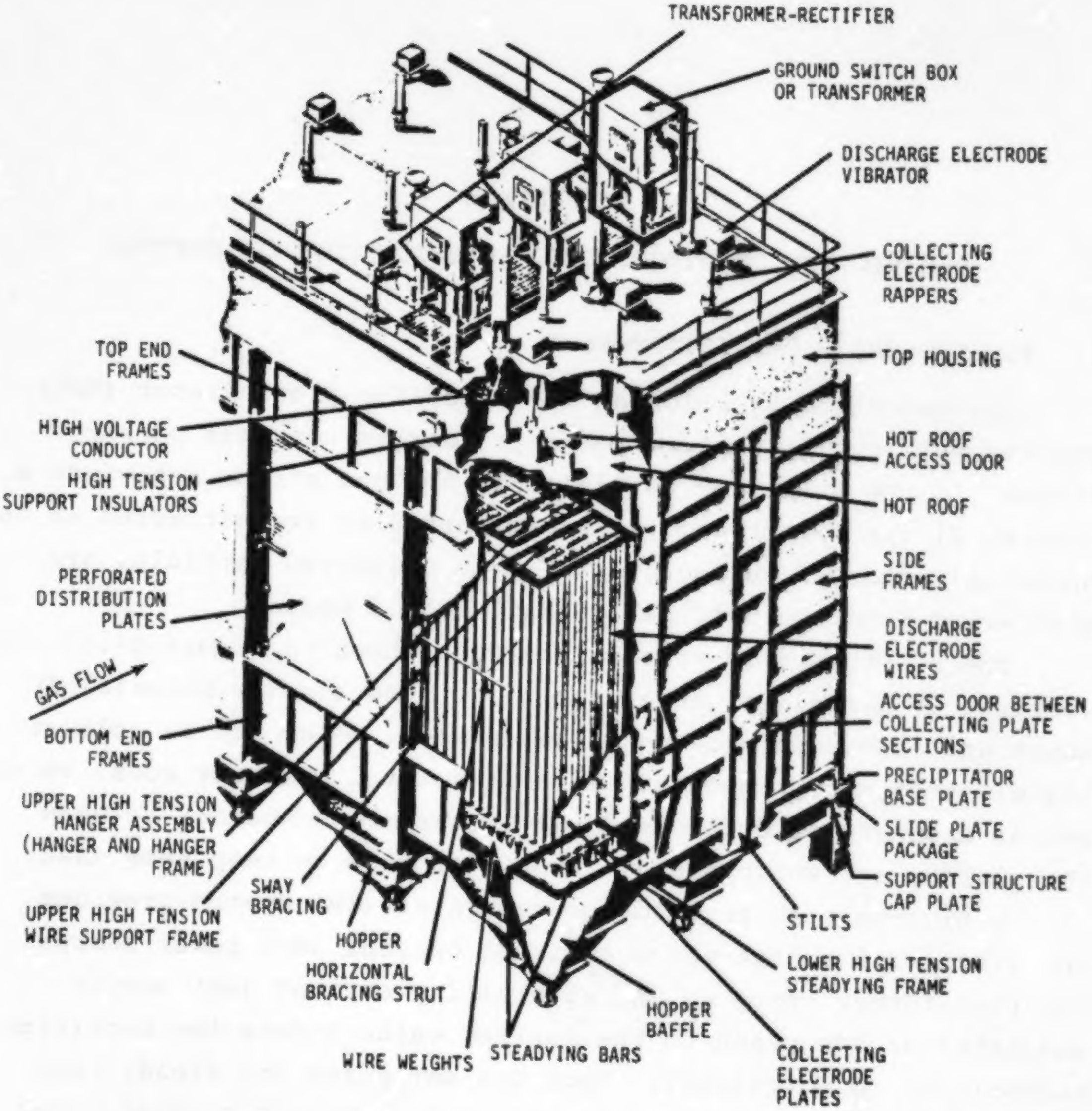

TRANSFORMER-RECTIFIER
GROUND SWITCH BOX OR TRANSFORMER
DISCHARGE ELECTRODE VIBRATOR
COLLECTING ELECTRODE RAPPERS
TOP END FRAMES
TOP HOUSING
HIGH VOLTAGE CONDUCTOR
HIGH TENSION SUPPORT INSULATORS
HOT ROOF ACCESS DOOR
HOT ROOF
SIDE FRAMES
PERFORATED DISTRIBUTION PLATES
DISCHARGE ELECTRODE WIRES
GAS FLOW
ACCESS DOOR BETWEEN COLLECTING PLATE SECTIONS
BOTTOM END FRAMES
PRECIPITATOR BASE PLATE
UPPER HIGH TENSION HANGER ASSEMBLY (HANGER AND HANGER FRAME)
SLIDE PLATE PACKAGE
SUPPORT STRUCTURE CAP PLATE
SWAY BRACING
UPPER HIGH TENSION WIRE SUPPORT FRAME
STILTS
HOPPER
LOWER HIGH TENSION STEADYING FRAME
HORIZONTAL BRACING STRUT
HOPPER BAFFLE
WIRE WEIGHTS
STEADYING BARS
COLLECTING ELECTRODE PLATES

Figure E-1. Typical electrostatic precipitator assembly with top housing.
(Courtesy of Research-Cottrell)

electrode plate area required per unit of gas flow rate (square feet per 1000 actual cubic feet of gas per minute), the gas flow rate and temperature, and the power density required by particle resistivity and size. The Deutsch-Anderson equation sets the relationship between required collection efficiency, velocity migration of the dust particles toward the collecting electrode, and the ratio of plate collection area to the gas volume:

$$\eta = (1-e^{-w\frac{A}{V}})\ 100$$

where η = efficiency, %

w = particle migration velocity, ft/s

A = plate area, ft^2

V = gas flow, ft^3/s

In operation, the precipitator efficiency is affected by the gas flow rate, gas temperature, and the electrical voltage and amperage used to create the electrostatic fields in the precipitator. The gas flow and temperature are established by the process unit from which the exhaust gas stream emanates. Normally, the voltage and current applied to the discharge electrodes are automatically controlled by the electrical rectifier circuit in response to an established electrical spark rate in the precipitator. As voltage increases, both precipitator efficiency and spark rate increase until excessive sparking overrides the efficiency gains from high voltage. A spark is a short circuit that causes a momentary voltage drop and efficiency loss.[3]

Figure E-2 illustrates the instrumentation required for monitoring and controlling an electrostatic precipitator installation. These instruments fall into two classifications: 1) direct instrumentation (directly involved in ESP operation), and 2) indirect instrumentation (indirectly associated with ESP operation).

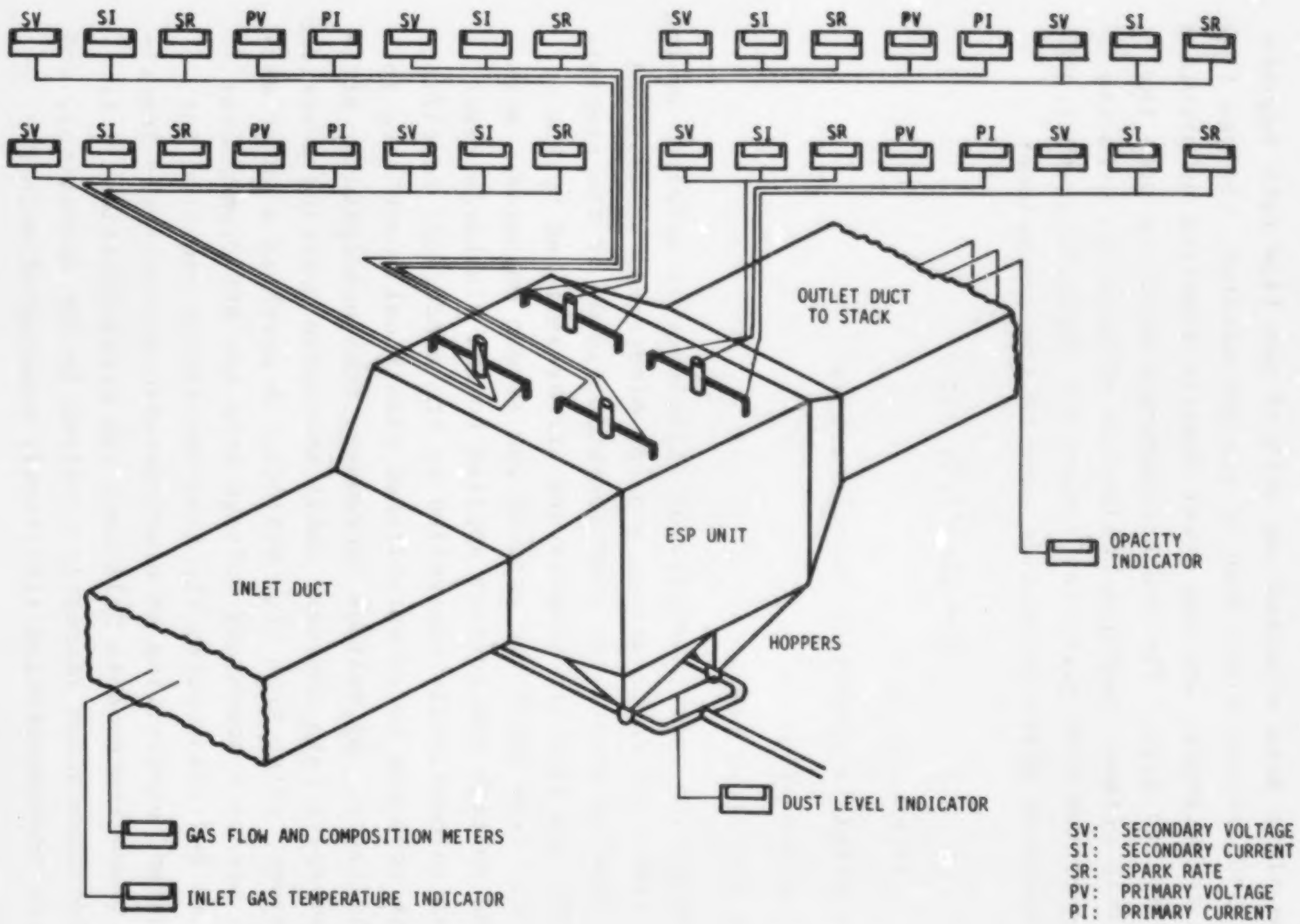

SV
SI
SR
PV
PI
SV
SI
SR
SV
SI
SR
PV
PI
SV
SI
SR
OUTLET DUCT TO STACK
ESP UNIT
INLET DUCT
HOPPERS
OPACITY INDICATOR
DUST LEVEL INDICATOR
GAS FLOW AND COMPOSITION METERS
INLET GAS TEMPERATURE INDICATOR
SV: SECONDARY VOLTAGE
SI: SECONDARY CURRENT
SR: SPARK RATE
PV: PRIMARY VOLTAGE
PI: PRIMARY CURRENT

Figure E-2. ESP Instrumentation Diagram.[1]

Direct Instrumentation

The instruments directly involved with ESP operation are those that relate to the electrical power used to charge the precipitator electrodes. These instruments measure the supplied voltage and current, the electrode voltage and current, and the spark rate for the electrodes for each transformer-rectifier set in the ESP. Figure E-3 shows the arrangement of meters on a typical control panel.

Indirect Instrumentation

Those instruments indirectly associated with ESP operation are those that measure parameters that affect or are affected by ESP performance. These instruments measure the inlet gas flow rate and temperature, the oxygen and carbon monoxide content of the exhaust gas, outlet gas opacity, and levels of particles in the collecting hoppers (see again Figure E-2). Measurement readouts are made at the ESP control panel. Figures E-4 and E-5 show examples of these panel meters.

II. FABRIC FILTERS

A fabric filter system consists of a woven or felted textile material, usually in the shape of a cylindrical bag, housed in a metal enclosure having inlet and outlet gas connections, a dust discharge hopper, and a means for periodic cleaning of the fabric.[4] Figure E-6 depicts a fabric filter system.

The particulate-laden gas enters the filter through the inlet gas connection and passes through the filtering medium, where the particulate matter is retained. The gas then leaves the filter via the outlet gas connection.

The operation cycle of most fabric filters has two phases: 1) a filtration phase during which material is deposited on the fabric while the pressure drop across the deposited material increases and the total flow decreases; 2) a cleaning phase, with

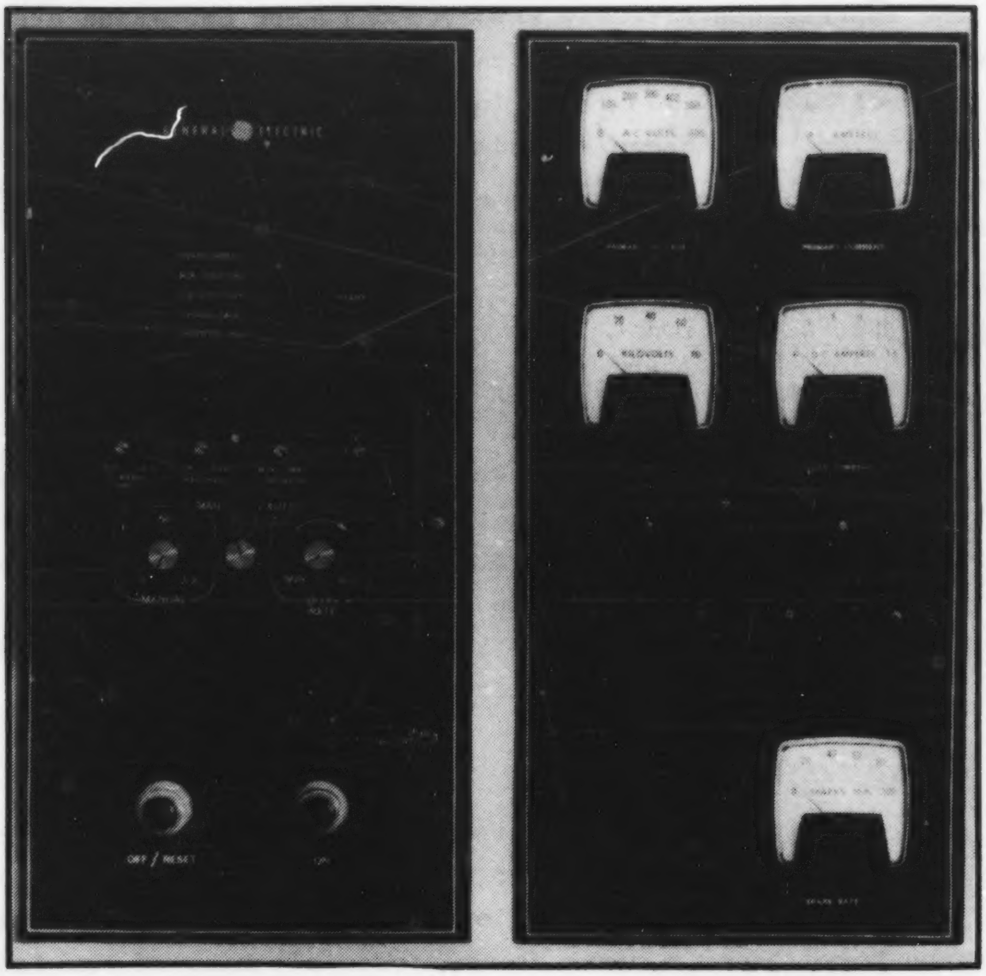


Figure E-3. Typical ESP control panel.
(Courtesy of Babcock and Wilcox Co.)

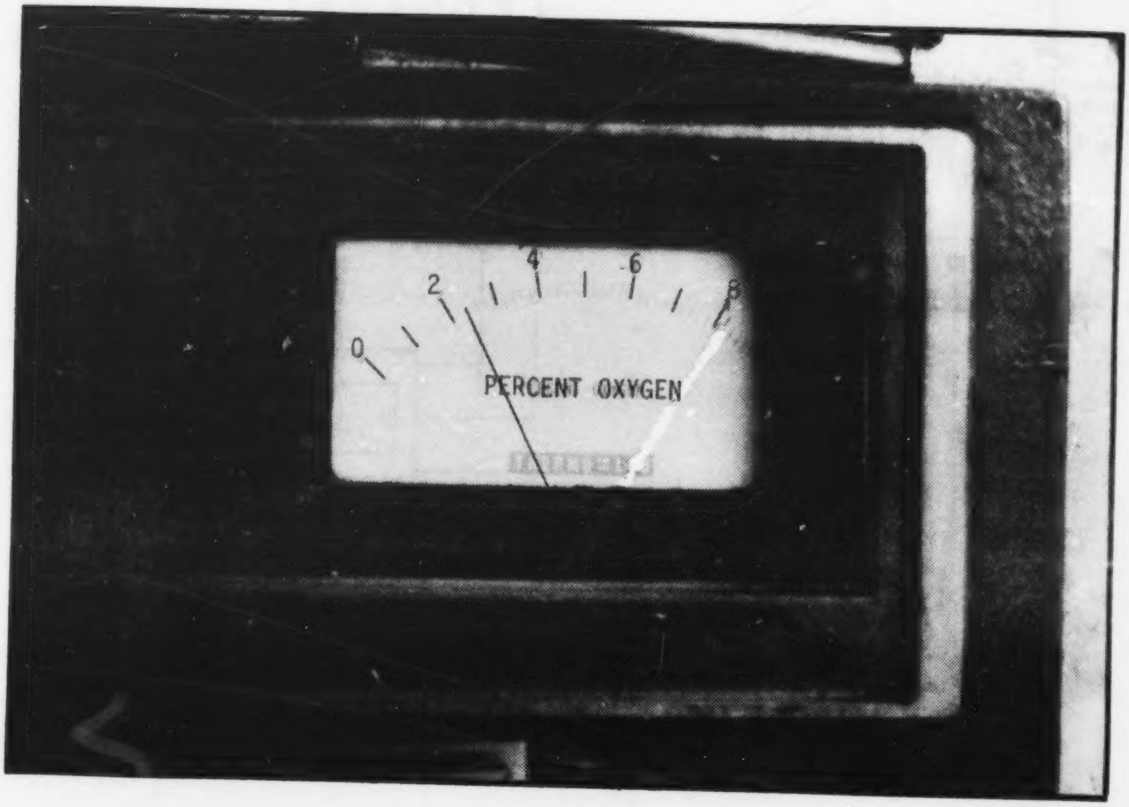

0
2
4
6
8
PERCENT OXYGEN

Figure E-4. Photograph of an oxygen meter on a control board.[3]

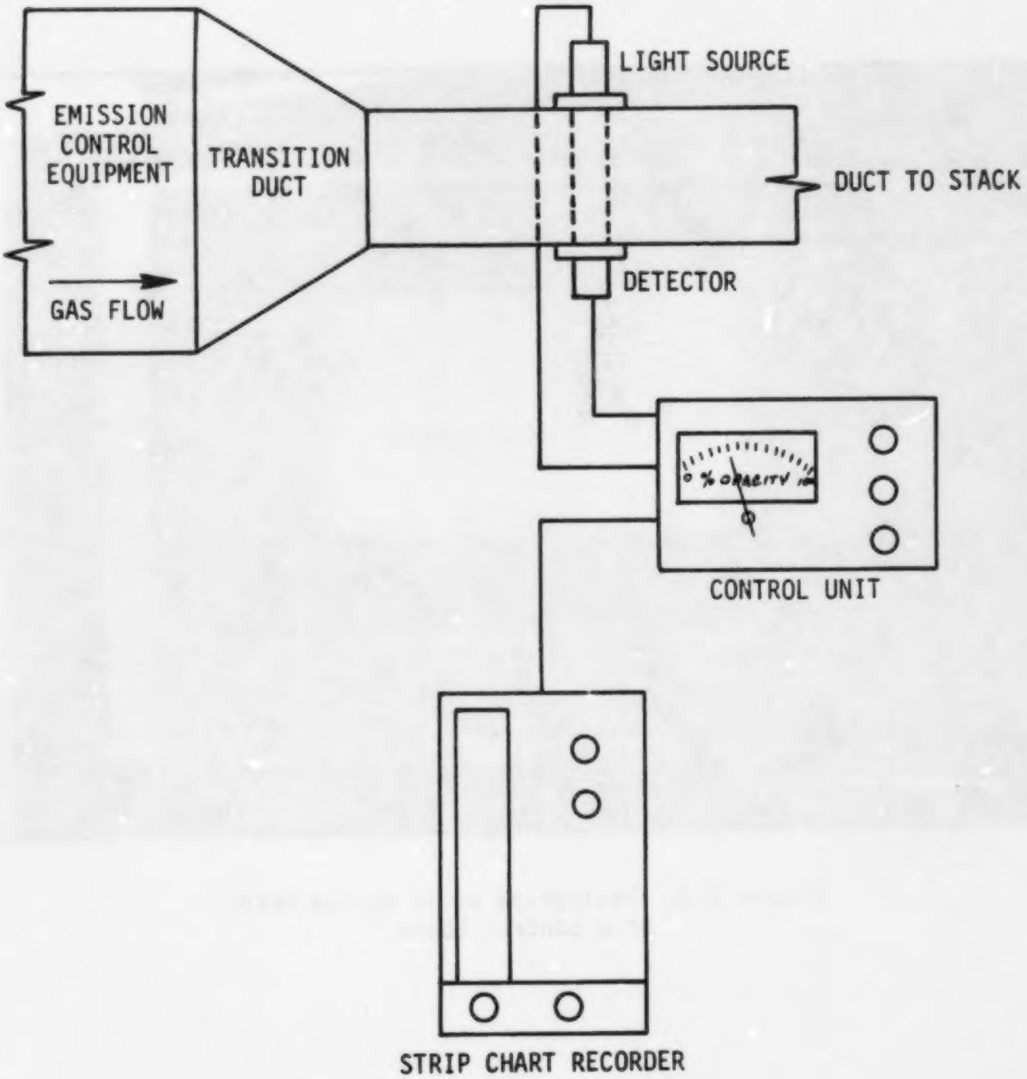

LIGHT SOURCE
EMISSION CONTROL EQUIPMENT
TRANSITION DUCT
DUCT TO STACK
GAS FLOW
DETECTOR
0 % OPACITY 100
CONTROL UNIT
STRIP CHART RECORDER

Figure E-5. Connection diagram of the opacity monitoring system.[1]

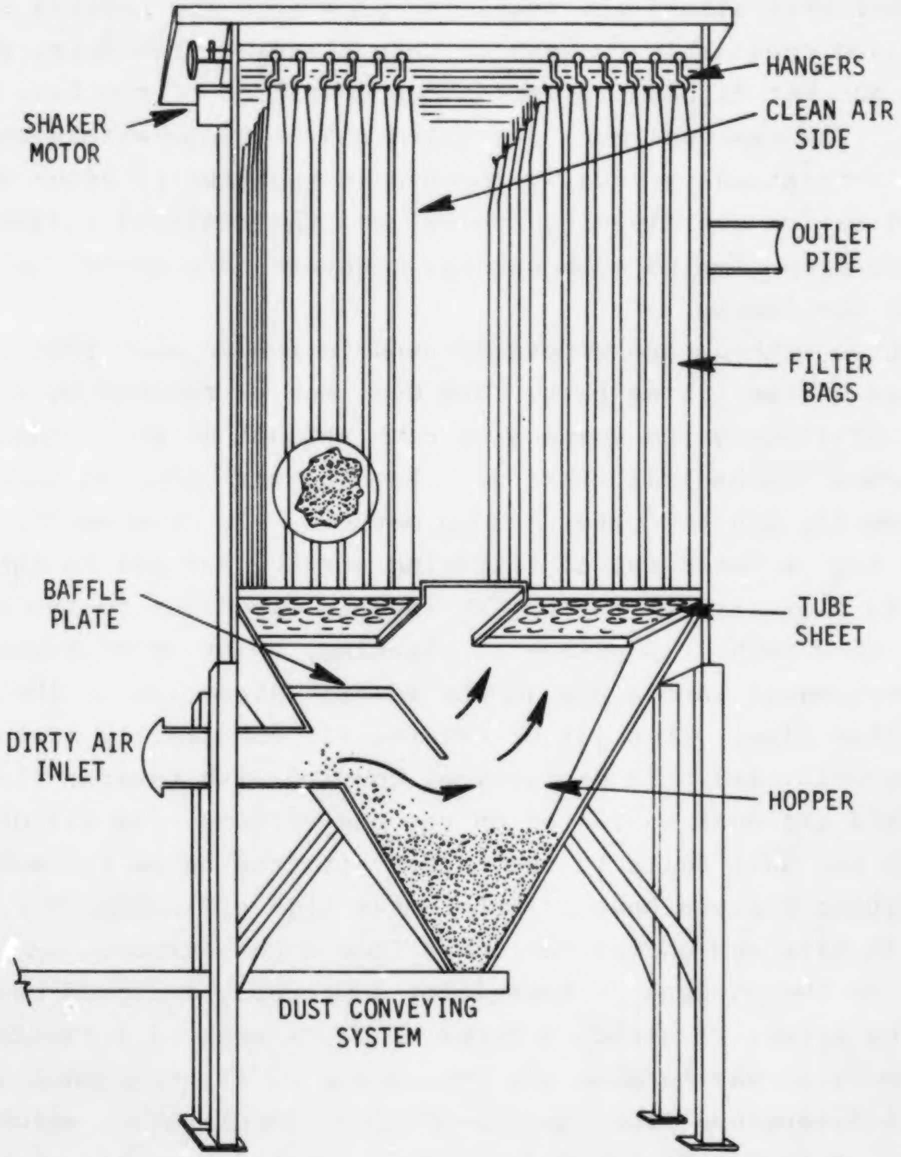

HANGERS
CLEAN AIR SIDE
SHAKER MOTOR
OUTLET PIPE
FILTER BAGS
BAFFLE PLATE
TUBE SHEET
DIRTY AIR INLET
HOPPER
DUST CONVEYING SYSTEM

Figure E-6. Typical fabric filter arrangement with shaker for dust removal.
(Courtesy of Wheelabrator-Frye Corporation [Wheelabrator Dust-Tube])

no filtration flow during dust removal. One at a time, compartments of bags are shut down and isolated from the gas flow for cleaning; this allows the total gas flow from the process to be maintained reasonably constant. This cleaning procedure, which can be automatic, permits continuous operation of the fabric filter. The residual dust deposited and retained within the fabric interstices gradually reaches an equilibrium after numerous filtration and cleaning cycles, and the residual filtering pressure drop remains more or less constant throughout the useful life of the fabric.

Three methods are generally used to remove dust from the surfaces of the filter bags. The dust may be removed by vigorously oscillating the suspension rack through an amplitude of a few inches (mechanical shaking). Reverse-air cleaning and pulse-jet cleaning are two other common methods. In reverse-air cleaning, a bag is taken out of filtering service and air is introduced to flow through the bag in reverse direction to the normal filter flow path. In pulse-jet cleaning, a jet of high pressure air is released into a bag in the reverse direction to the regular filter flow. This jet of reverse air momentarily distends the bag wall, and this distension, coupled with reverse flow, dislodges the dust collected on the bag surface. In all of these methods the dust falls to the hopper situated below for removal.

Fabric filters have an inherently high efficiency for removing both fine and coarse particles from a gas stream. An efficiency of 99+ percent is normal for a properly designed unit.

The filter is sized in terms of cloth area as a function of the amount of gas handled and the method of filter cleaning. The area is determined from the air-to-cloth (A/C) ratio, which is arrived at by dividing total air flow (in acfm) by the cloth area (in square feet). Thus, the ratio is expressed in acfm/ft^2.

The instrumentation required for monitoring a fabric filter installation consists mainly of differential pressure gages. Each isolatable compartment should be equipped with such a gage so that the condition of the bags within the compartment can be determined. The pressure gages are locally mounted on the filter units, as illustrated in Figure E-7. The photograph in Figure E-8 shows the total instrument array as viewed from the end of a fabric filter installation.

Awareness of the flow rate and temperature of the inlet gas stream is also essential to the proper operation of a fabric filter. The gas stream temperature is normally a part of the information gathered for process control purposes and appears on a central control panel of the process to which the filter unit is attached. Measuring the fan motor current gives an indication of fan horsepower, which can be used to determine the flow rate by using gas stream temperature, the fan speed in rpm, and fan curves provided by the fan manufacturer. Where the gas temperature is critical by reason of its proximity to the upper operating limit of the fabric used, temperature limit switches are used to activate dampers on the inlet side of the fabric filter unit or water spray nozzles. The dampers admit ambient air to the filter unit and thus prevent thermal damage. The nozzles introduce water to evaporatively cool the gas stream.

III. CYCLONE SEPARATORS

A cyclone separator uses centrifugal force to remove particulate from a gas stream. As shown in Figure E-9 the dust-laden gas enters the upper cylindrical section tangentially, which produces a centrifugal force that preferentially throws the larger, heavier particles outward to the walls of the cylinder. The gas spirals downward into the conical section, where the gas velocity increases and greater centrifugal force is generated. The particulate matter collected at the walls is swept to the bottom of the cone section, where it is discharged through a valve into a collection hopper or drum. The cleaned gas exits from the unit through an outlet at the top center of the cylindrical section.

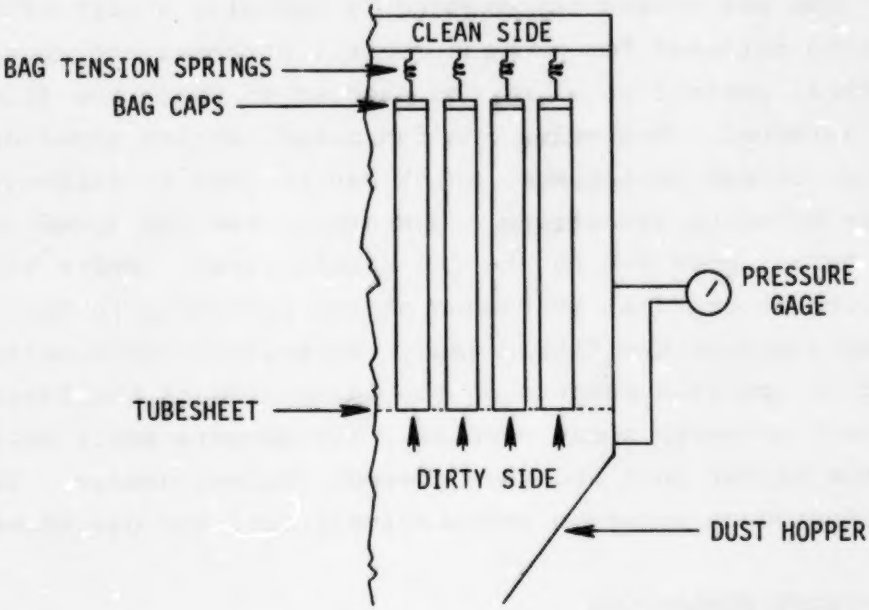

CLEAN SIDE
BAG TENSION SPRINGS
BAG CAPS
PRESSURE GAGE
TUBESHEET
DIRTY SIDE
DUST HOPPER

Figure E-7. Cross section of fabric filter, showing filter internals and a pressure gage.[3]

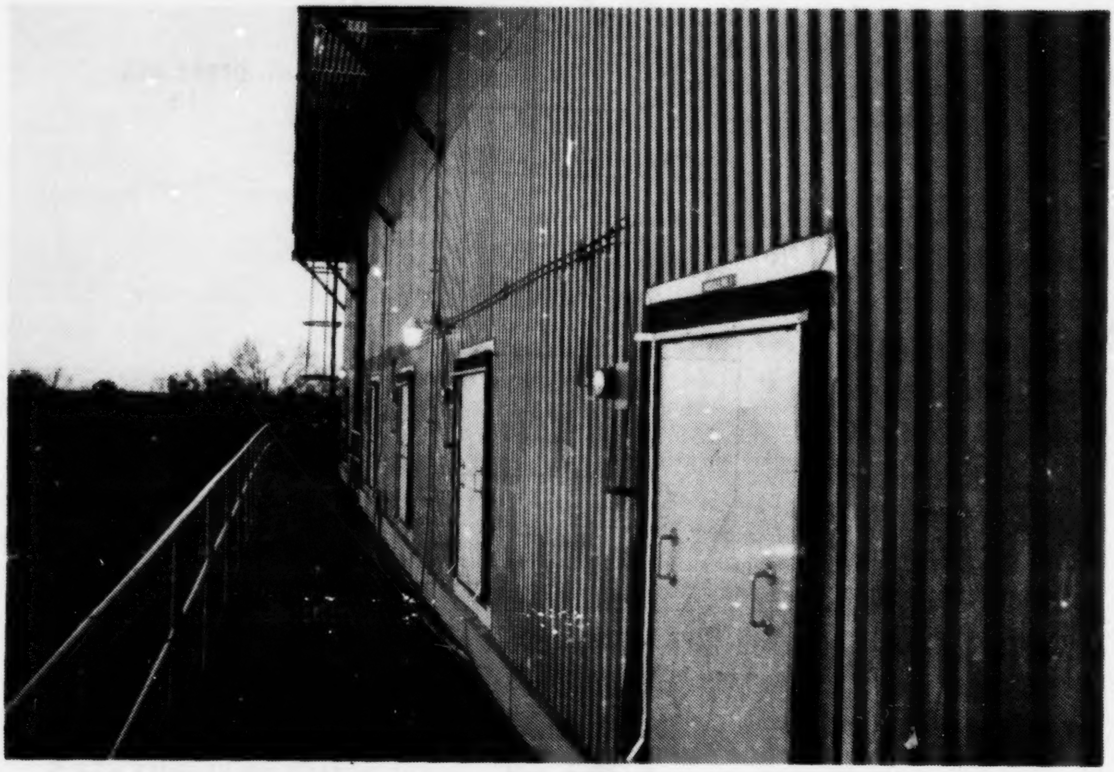
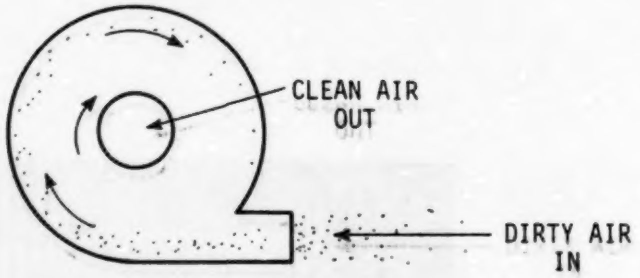


Figure E-8. Photograph of fabric filter, showing upper and lower catwalk, compartment access doors, and Magnehelic® gages.[3]


CLEAN AIR
OUT
DIRTY AIR
IN

TOP VIEW OF CYCLONE

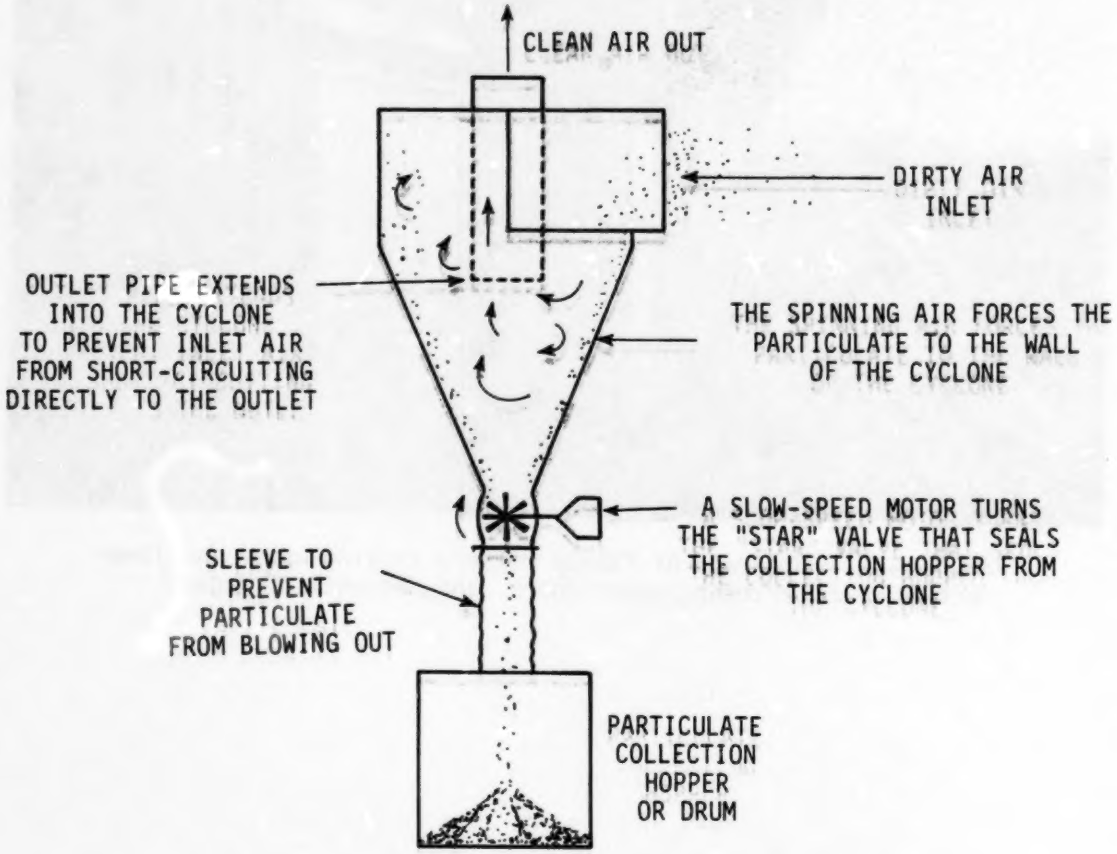

CLEAN AIR OUT
DIRTY AIR
INLET
OUTLET PIPE EXTENDS
INTO THE CYCLONE
TO PREVENT INLET AIR
FROM SHORT-CIRCUITING
DIRECTLY TO THE OUTLET
THE SPINNING AIR FORCES THE
PARTICULATE TO THE WALL
OF THE CYCLONE
A SLOW-SPEED MOTOR TURNS
THE "STAR" VALVE THAT SEALS
THE COLLECTION HOPPER FROM
THE CYCLONE
SLEEVE TO
PREVENT
PARTICULATE
FROM BLOWING OUT
PARTICULATE
COLLECTION
HOPPER
OR DRUM

Figure E-9. Flow diagram of a dry cyclone collector.[3]

A single cyclone separator unit may be utilized for particulate removal from a given gas stream, but the use of several smaller separators in a parallel arrangement enhances separation efficiency. When multiple cyclone separators are used, gas distribution and pressure drop across them must be relatively equal to achieve the maximum efficiency benefit.

The comparative advantages of cyclones include the relatively small amount of space occupied, low capital investment and operating costs, and modest pressure drop.[5] Figure E-10 shows the fraction of dust emitted (penetration) for three sizes of multiple cyclones at various particle sizes. The larger-sized tubes have a lower pressure drop and lower collection efficiency.[6]

The performance of the cyclone separator is not sensitive to temperatures or such particulate properties as electrical resistivity or filterability. Particulates with high moisture content, however, tend to plug the discharge tube. The operating parameters of interest are the gas flow rate and the pressure drop across the separators.

Because the design of the cyclone separator is such that operation at an optimum gas flow rate is necessary for the most efficient separation of particulates from the gas, the gas flow rate and pressure differential across the separator provide indicators of the relative efficiency of the separator's operation. Figure E-11 presents a data sheet of typical information on a cyclone separator.

The only instrumentation required for cyclone separators is a differential pressure gage calibrated in inches of water for each separator. The gages should be locally mounted where they are relatively accessible and easy to read. Gas stream temperature readings can be obtained from the instrumentation at the appropriate process control panel, and gas flow rate can be calculated by recording fan motor current and speed.

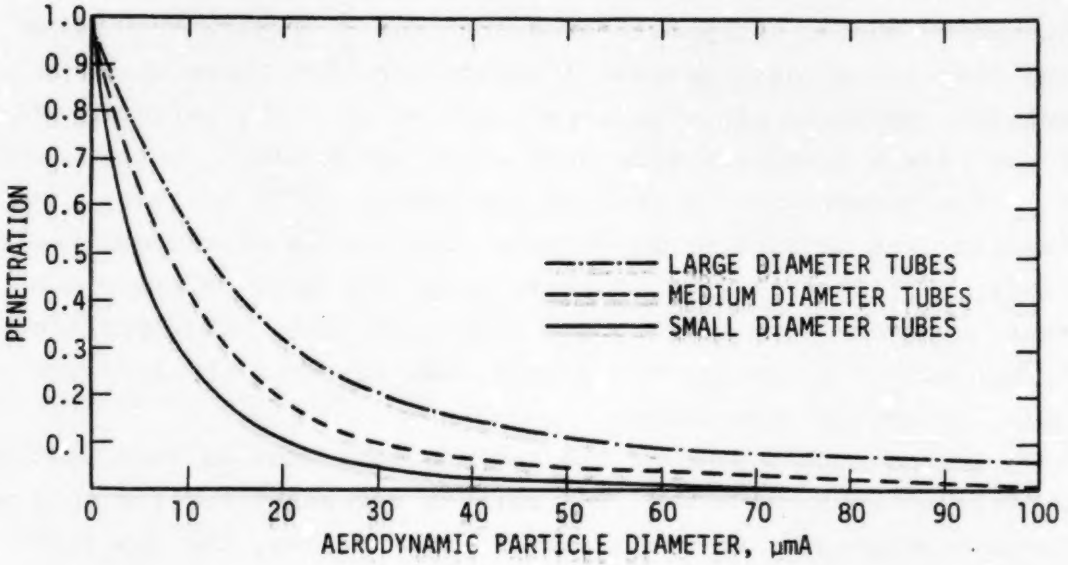


Figure E-10. Penetration curves for multiple cyclone tubes of different diameter.[5]

CYCLONE DESCRIPTION

Source Name XYZ Industries

Date Nov. 20, 1980

Inspector I. Inspector

Cyclone No. C-1

Type of cyclone multicyclone

Installation date 1976

Manufacturer Multi-Cyclone Co. Model#

Number of tubes 6

Dimensions 4-inch diameter

	Design	Actual
Gas flow, acfm	108,000	49,000
Gas temperature, °F	405	400
Pressure drop across the collector, in. water	5	3.1

Audible air leakage at hatches No

Solids discharge rate, characterize Rotary valve turning at 4 rpm

Comments:

SKETCH THE CYCLONE SYSTEM

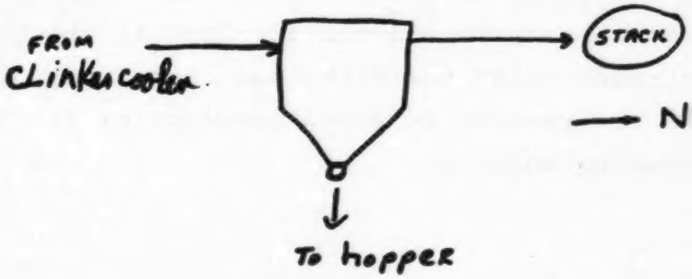


Figure E-11. Example of cyclone description data sheet.[3]

IV. GRAVEL-BED FILTERS

The gravel-bed filter applies the principles of centrifugal force and impingement to the removal of particulates from an exhaust gas stream. As depicted in Figure E-12, as the particulate-laden gas enters the gravel-bed filter, it is subjected to centrifugal forces which move the larger particulates outward to the walls, from which they subsequently fall to the bottom for removal via an air lock. The partially cleaned gas first flows up through a riser to one or more filter chambers located above and then passes down through gravel beds, which are each approximately 4-1/2 inches in depth and supported on wire mesh screens. The particulate in the gas impinges upon the gravel surface and is captured by deposition. The cleaned gas stream from the beds is exhausted through a clean-gas chamber into an exhaust duct that conveys it to a stack for discharge to the atmosphere.

After a module has been in service a while, the gravel-bed filter becomes clogged with collected particulate. It must be removed from service at regular intervals and subjected to cleaning by backflushing it with air. The agglomerated dust is blown from the bed and the bed rake mechanism is used to stir the bed. The entrained particles from the bed pass down through the riser tube into the collector section, where a major portion of them settle out and are removed via the air lock at the bottom. The remaining particles enter the dirty gas duct, where they either settle out and are removed by screw conveyor or are removed by the other operating modules.

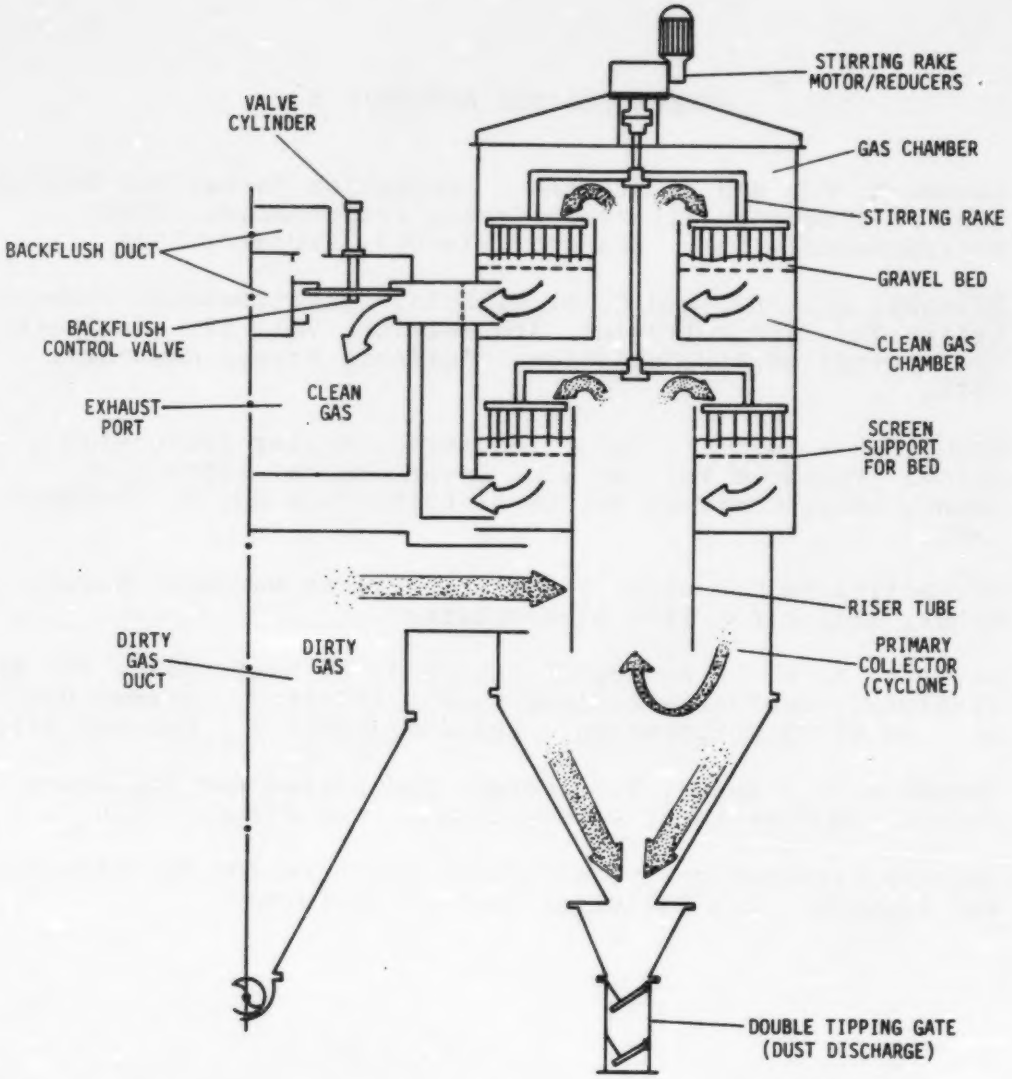

STIRRING RAKE MOTOR/REDUCERS
VALVE CYLINDER
GAS CHAMBER
STIRRING RAKE
BACKFLUSH DUCT
GRAVEL BED
BACKFLUSH CONTROL VALVE
CLEAN GAS CHAMBER
EXHAUST PORT
CLEAN GAS
SCREEN SUPPORT FOR BED
RISER TUBE
DIRTY GAS DUCT
DIRTY GAS
PRIMARY COLLECTOR (CYCLONE)
DOUBLE TIPPING GATE (DUST DISCHARGE)

Figure E-12. Gas flow diagram for a gravel-bed filter.[7]
(Courtesy of Rexnord Corporation)

REFERENCES fOR APPENDIX E

1. Szabo, M. F., and Y. M. Shah. Inspection Manual for Evaluation of Electrostatic Precipitator Performance. PEDCo Environmental, Inc. EPA-340/1-79-007, February 1979.

2. Oglesby, S., Jr., and G. B. Nichols. Electrostatic Precipitation In: Air Pollution, 3rd Edition, Vol. IV. Engineering Control of Air Pollution. Academic Press, New York. 1977.

3. PEDCo Environmental, Inc. Industrial Boiler Inspection Guide. Prepared for the U.S. Environmental Protection Agency under Contract No. 68-01-6310, Task No. 9. October 1981.

4. The McIlvaine Company. The Fabric Filter Manual. Northbrook, Illinois. 1975 plus updates.

5. Barrett, K. W. A Review of Standards of Performance for New Stationary Sources--Portland Cement Industry. Metrek Division of MITRE Corporation. EPA-450/3-79-012. October 1978.

6. Theodore, L., and A. Buonicore. Industrial Air Pollution Control Equipment for Particulates. CRC Press. 1976.

7. Rexnord Corporation. Descriptive Brochure for Rex Gravel-Bed Filters. Air Pollution Control Division.

APPENDIX F

A PORTLAND CEMENT INSPECTION REPORT PLANT, USA

by

Inspector
Environmental Protection Agency

A PORTLAND CEMENT INSPECTION REPORT
PLANT, USA

I. INTRODUCTION

On April 8, 1981, Inspector , inspected A Portland Cement Company, plant, , Texas. The mailing address of the firm is the same. The Vice President of A Portland is ; the corporate mailing address is . I met with Mr. , Plant Manager, and , Production Manager, and informed them of the nature of the inspection.

II. ACTIVITY SUMMARY

I arrived at the plant at 10:15 a.m. and observed the cement operations. I contacted and and discussed the plant operations and air pollution control equipment. I then inspected , the cement plant, and the particulate control devices with . I inspected the cement plant Kiln No. 3 with regard to New Source Performance Standards. During the inspection, I read visible emissions from the Kiln 2 clinker cooler. The VEO form is in Appendix A.

III. PROCESS DESCRIPTION

This cement plant (Photograph No. 1) uses about 180 tons/h of limestone, shale, sand, and iron ore in a water slurry to make cement by the wet process. The limestone and shale are quarried at the site. Sand, iron ore, and gypsum are purchased from outside sources.

Raw materials (limestone and shale) are mined in a quarry (Photograph No. 2). The quarried materials are transferred to the primary crusher by truck or conveyor (Photograph No. 3). A Stanler feeder breaker reduces the limestone to a size suitable for conveyor handling (8 inches or less in diameter). The primary crushing facility (Photograph No. 5) is equipped with a hammermill. The hammermill particulate emissions are controlled by a fabric filter (Photograph No. 6). The crushed material (3/4-inch diameter or less) is conveyed to the raw material storage building (Photograph No. 7).

Sand, iron ore, and gypsum are received by truck or railcar. Iron ore is stored in the raw mill feed bins or raw material storage building. The gypsum is stored in another silo.

Limestone, shale, sand, and iron ore are milled and combined with water into a 40 weight percent water slurry. The slurry is stored in the kiln feed storage tanks (Photograph No. 8). Slurry is fed into one of three coal-fired rotary kilns (Photographs No. 8 and 9). Particulate emissions from each kiln are controlled by an ESP on the feed inlet of the kiln (Photograph No. 9). Cement clinker cooler particulate emissions at the outlet of the kiln are controlled by fabric filters. The fabric filter stack outlets are shown as EPN 3, EPN 7, and EPN 13 (Photograph No. 9). Clinker is generally stored in silos (Photograph No. 10). During the winter the company makes excess clinker, which is stored in an outside pile (Photograph No. 11) adjacent to the raw material storage building. Clinker and gypsum are fed to two finish mills, where the materials are milled into finish cement. Two fabric filters control emissions from these mills. One fabric filter exhaust vent is shown in Photograph No. 12. Finished cement from the mills is transferred to storage silos and then shipped out by truck (occasionally by railcars) (Photograph No. 13). Two fabric filters control emissions from the finished cement storage silos. The fabric filter vents are shown in Photographs No. 14 and 15.

The company uses coal to fuel the kilns. Coal is received by railcars which are unloaded at a maximum of 1700 tons/8 hours (Photograph No. 16). Particulate emissions during unloading are controlled by a water spray system. The coal is stored in piles (Photograph No. 17). The company blends 85 to 90 percent low-sulfur (0.5 percent) coal with 10 to 15 percent high-sulfur (2.5 to 4.0 percent) coal. After the coal is blended, it is conveyed to coal storage silos (Photograph No. 18) before it is crushed and fed into the kilns.

IV. OBSERVATION OF PROCESS

I inspected the following operations:

1. Quarry operations
2. Raw material crushing
3. Three kilns and clinker coolers
4. Two finish mills
5. Two truck loading facilities
6. Coal unloading and storage

The company normally hauls about 850 tons of limestone and shale per hour out of the quarry. The raw material is crushed to a size less than 3 inches in diameter at about 640 tons per hour. A fabric filter controls particulate emissions from the crusher. Raw material was being fed to Kilns 2 and 3 at a rate of 58 tons/h each. Kiln 1 was not operating. The two kilns were burning about 17 tons of coal per hour. The visible kiln stack emission in Photograph No. 1 is a steam plume. The clinker cooler stack on Kiln 2 had visible emissions from 0 to 10 percent opacity. The finish mills were operating at 59 tons/h each. Truck loading was operating at 250 tons/h during the inspection. There was no coal being conveyed during the inspection.

On August 11, 1978, the company was issued a PSD permit to add a dry kiln process to the existing wet plant operation. The company has not begun construction of the plant for economic reasons.

INSPECTION CHECKLIST

Date(s) of Inspection April 8, 1981

Time In 10:15 a.m. Out 3:00 p.m.

Company name A Portland Cement Company, Inc.

Mailing address

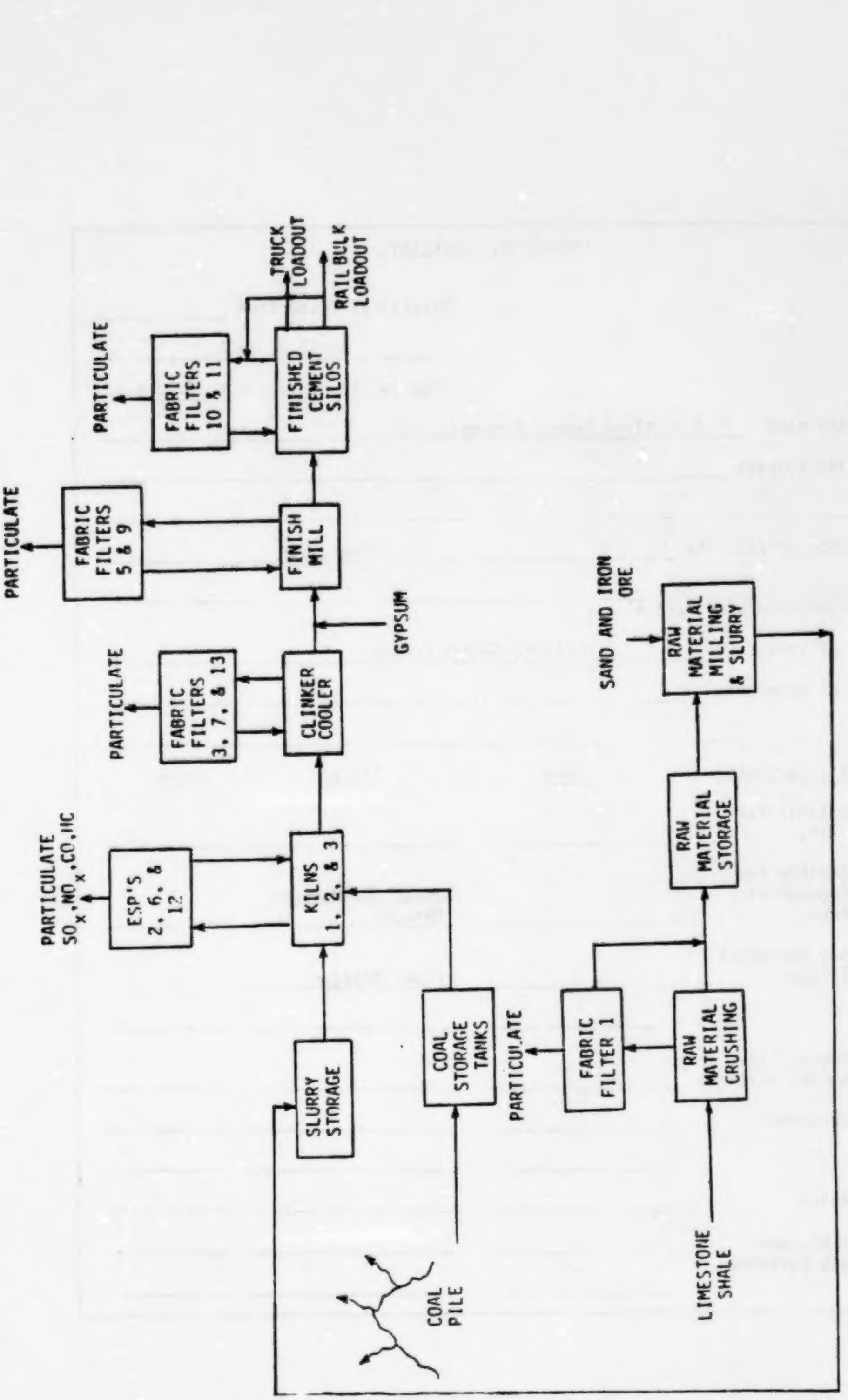
Location of facility Plant, USA

(Include county or parish)

Type of industry Portland Cement Company

Form of ownership

Company personnel	Name	Title	Phone
Responsible for facility			
Responsible for environmental matters		Production Manager Manager	
Company personnel contacted		Plant Manager	
Confidentiality Statement given to			
EPA personnel			
Inspector			
State or local agency personnel			



COAL PILE
LIMESTONE SHALE
COAL STORAGE TANKS
SLURRY STORAGE
RAW MATERIAL CRUSHING
FABRIC FILTER 1
PARTICULATE
RAW MATERIAL STORAGE
RAW MATERIAL MILLING & SLURRY
SAND AND IRON ORE
KILNS 1, 2, & 3
ESP'S 2, 6, & 12
PARTICULATE SOx, NOx, CO, HC
CLINKER COOLER
FABRIC FILTERS 3, 7, & 13
PARTICULATE
GYPSUM
FINISH MILL
FABRIC FILTERS 5 & 9
PARTICULATE
FINISHED CEMENT SILOS
FABRIC FILTERS 10 & 11
PARTICULATE
TRUCK LOADOUT
RAIL BULK LOADOUT

Process Flow Diagram.

PRODUCTION INFORMATION[1]

Process/Unit	Process Input Rate	Product	Production Rate			Emission Point (including fugitive emissions)	Status of Process at time of inspection
			Design	Actual			
				Avg.	Max.		
Raw material crushing	640	Raw feed	850.0	640.0	850.0	1	Not operating
Raw material grinding mill	108	Raw feed	120.0	108.0	120.0	--	108
Raw material grinding mill	108	Raw feed	120.0	108.0	120.0	--	108
Kiln 1	38	Clinker	39.5	38.0	39.5	2,3	Not operating
Kiln 2	38	Clinker	39.5	38.0	39.5	6,7	38
Kiln 3	38	Clinker	39.5	38.0	39.5	12,13	38
Finish mill	59	Cement	65.0	59.0	65.0	5,9	59
Finish mill	59	Cement	65.0	59.0	65.0	5,9	59
Truck loadout No. 1	300	Cement	300.0	250.0	300.0	10,11	250
Truck loadout No. 2	300	Cement	300.0	250.0	300.0	10,11	Not operating
Coal feed to kilns	25	Heat	25.0	20.0	25.0	2,6,12	16.6

---

[1] Production rates are in ton/h unless stated otherwise

EMISSION POINT INFORMATION*

Emission Point	Process/Unit Description	Stack Data				Emission Rate				
		Ht. (ft)	Dia. (ft)	Flow Rate (acfm)	Exit Temp (°F)	Part. (lb/h)	SO_2 (lb/h)	HC (lb/h)	CO (lb/h)	NO (lb/h
1	Raw material crushing	25	1.8	8,900	70	1.14				
2	Kiln No. 1	150	10.5	231,000	515	34.00	148.6			98.8
3	Kiln No. 1 clinker cooler	52	5.5	31,600	231	3.00				
4	Clinker storage	110	4.2	8,000	70	1.03				
5	Finished cement mill	51	4.2	57,500	150	5.57				
6	Kiln No. 2	150	9.3	200,000	446	18.50	148.6			98.8
7	Kiln No. 2 clinker cooler	52	5.5	28,300	189	1.27				
8	Clinker storage	94	1.6	8,000	70	1.03				
9	Finished cement mill	51	4.2	57,500	150	5.57				
10	Cement storage	157	1.8	11,000	125	1.25				
11	Cement storage	157	1.8	11,000	125	1.25				
12	Kiln No. 3	150	9.3	130,000	219	6.5	148.6			98.8
13	Kiln No. 3 clinker cooler	52	5.5	32,800	211	0.56				

*Attach Record of Visual Determination of Opacity for each visible emission.

ABATEMENT EQUIPMENT INFORMATION

Type	PARAMETERS (Fill in applicable data)*					
	Pressure Drop (inches water)(a)	GPM water(b)	ACFM (c)	Voltage (d)	Amps (e)	Spark Rate (f)
Fabric filter	6		8,910			
Electrostatic precipitator	--		231,000	60	55	None
Fabric filter	7		31,600			
Fabric filter	6		8,000			
Fabric filter	6		57,500			
Electrostatic precipitator	--		200,000	60	55	None
Fabric filter	7		29,300			
Fabric filter	6		8,000			
Fabric filter	6		57,500			
Fabric filter	6		11,000			
Fabric filter	6		12,000			
Electrostatic precipitator	--		130,000	104	80	None
Fabric filter	7		32,800			

*Parameters required for various devices:

(1) Cyclone - (a)(c)
(2) Fabric filter - (a)(c)
(3) Scrubbers - (a)(b)(c)(g)
(4) ESP - (c)(d)(e)(f)
(5) Others
Gravity Chambers - (a)(c)
Thermal Reaction - Operating Temperature, Residence time
Chemical Reaction - Solution concentration and flow rate

This checklist should be filled out only for hydrocarbons with vapor pressures greater than 1.5 psia at storage conditions.

STORAGE

Tank No.	Capacity (units)	Type (1)	Product Stored	Vapor Pressure (units) @ Max. Storage Temp	Maximum Storage Temp.	Vapor (2) Controls	Remarks*
21	2000	U	Gasoline	6.2	70	SF	

Footnotes:

(1) C = fixed roof; F = floating roof; p = pressure; O - open top; S = spheroid; H = horizontal; U = underground

(2) N = None, CV = conservation vents; F = floating roof (SS = single seal; DS = double seal); VR = Vapor recovery (describe); VD = vapor disposal (describe); VB = vapor balance; SF = submerged fill.

* Date installed, etc.

VOLATILE HYDROCARBON LOADING/UNLOADING FACILITIES

Loading Facility Designation	Source	Type Transfer/Size (RR Cars, Trucks)	Monthly Thru-put (1000 Gal)	Type Vapor Control System	Submerged Loading	Products	
						Type	Vapor Pressure (psia)
		None					

STATIONARY GASOLINE STORAGE CONTAINER(S)

Emission Point	Container Size	Date Installed	Submerged Fill Line	Type Roof	Vapor Recovery System Type
None					

WATER SEPARATOR

Emission Point	Volatile Hydrocarbons		Amount Volatile Hydrocarbon Entering/day	Type Vapor Control
	Type Separated	Vapor Pressure (psia)		
None				

ORGANIC SOLVENT EMISSIONS

Types of Operation None

Max. Amount Emitted Per Hour: ______________ /Hr ______________
Method Used To Determine ______________
Max. Amount Emitted Per Day: ______________ /Day ______________
Method Used To Determine: ______________

Controls On Emissions: ______________

FIELD OBSERVATIONS SUMMARY

Emission Point	Opacity Reading	Time		Comments
		Start	End	(Instantaneous Reading, 6 min. Reading, etc.)
7	0 to 5	1:11 p.m.	1:26 a.m.	Opacities from Kiln No. 2 clinker cooler fabric filter ranged from 0 to 10 percent over 15 minutes.

CEMENT KILN EMISSIONS

Plant burn = a combination of 85 to 90 percent low sulfur coal with 10 to 15 percent high sulfur coal. Average properties of the coal mixture are:

Sulfur = 0.7 to 0.8%
Ash = 10 to 13%
Heat content = 12,500 Btu/lb (dry basis)

The maximum kiln production is 38 ton/h cement. Using ESP's with efficiencies of 99.8 percent (from 1976 EIQ) and AP.42 emission factors* the kiln and dryer emissions are:

Particulate: Kiln emission factor = 228 lb/ton

$$228\ \text{lb/ton} \times 38\ \text{ton/h} \times \frac{100-99.9}{100} = 17.3\ \text{lb/h}$$

Dryer emission factor = 32 lb/ton

$$32\ \text{lb/ton} \times 33\ \text{ton/h} \times \frac{100-99.8}{100} = 2.4\ \text{lb/h}$$

Total = 17.3 + 2.4 = 19.7 lb/h

Sulfur dioxide: Mineral source emission factor = 10.2 lb/ton

75% adsorption of SO_2 by limestone dust

$$10.2\ \text{lb/ton} \times 8\ \text{ton/h} \times \frac{100-75}{100} = 96.9\ \text{lb/h}$$

Coal combustion emission factor = 6.85 (S = 0.8%) lb/ton

$$6.8\ \text{lb/ton} \times 0.8 \times 35\ \text{ton/h} \times \frac{100-75}{100} = 51.7\ \text{lb/h}$$

Total = 96.9 + 51.7 = 148.6 lb/h

Nitrogen oxides: Emission factor = 2.6 lb/ton

2.6 lb/ton x 36 ton/h = 98.8 lb/h

Using AP.42 emission factors kiln particulate emissions are 25.9 lb/h. Regulation I limits emissions to 84.8 lb/h. At a kiln feed rate of 58 ton/h, kiln emissions from stack tests are:

$$6.5\ \text{lb/h} \times \frac{1}{58\ \text{ton/h}} = 0.11\ \text{lb/ton of kiln feed}$$

NSPS limits kiln emissions to 0.3 lb/ton of kiln feed.

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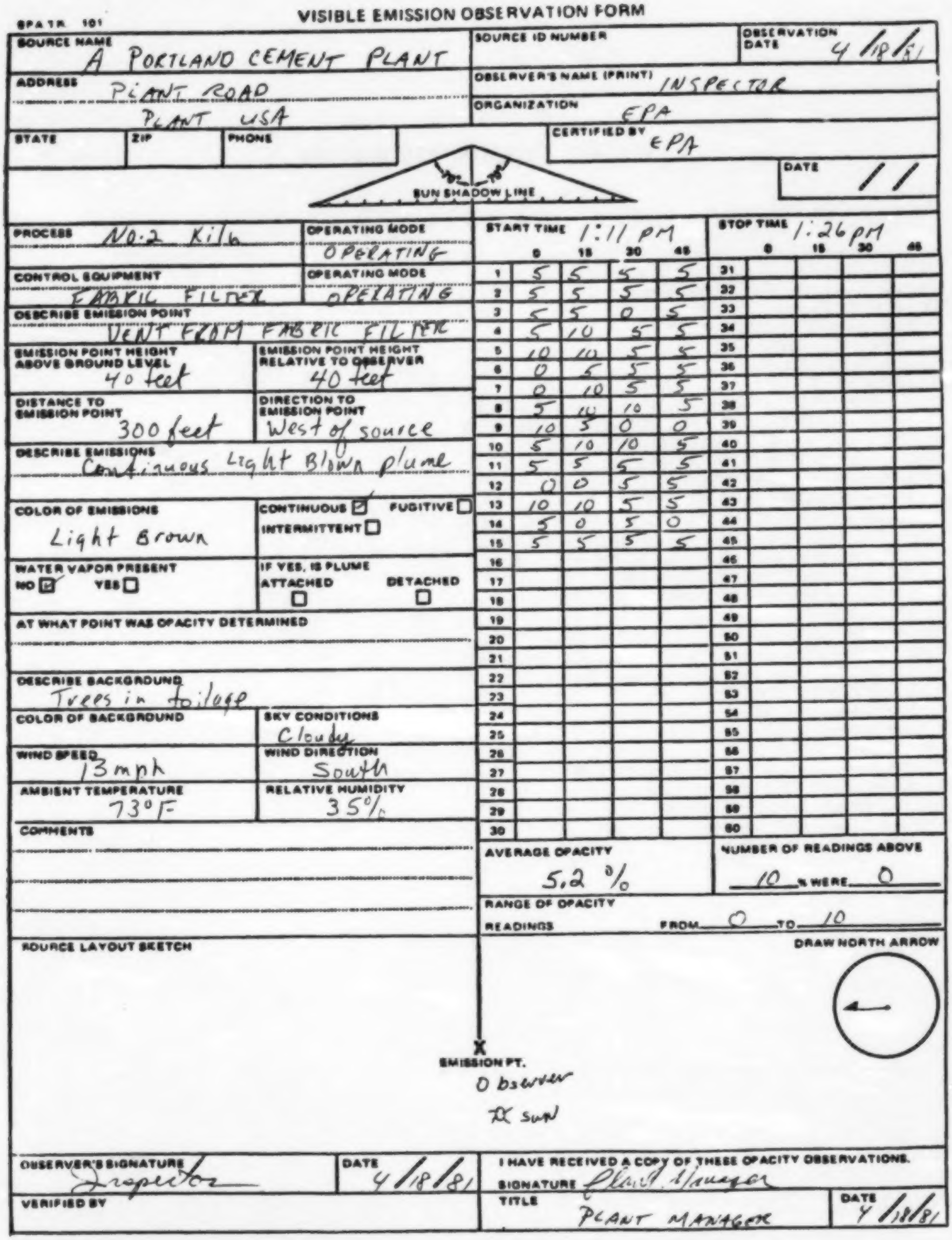
*AP.42, Page 8.6-3, Table 8.6-1, cement manufacturing emissions.

VISIBLE EMISSION OBSERVATION



EPA TR 101

VISIBLE EMISSION OBSERVATION FORM

SOURCE NAME A PORTLAND CEMENT PLANT

SOURCE ID NUMBER

OBSERVATION DATE 4/18/81

ADDRESS PLANT ROAD
PLANT USA

OBSERVER'S NAME (PRINT) INSPECTOR

ORGANIZATION EPA

STATE

ZIP

PHONE

CERTIFIED BY EPA

DATE / /

SUN SHADOW LINE

PROCESS No.2 Kiln

OPERATING MODE OPERATING

CONTROL EQUIPMENT FABRIC FILTER

OPERATING MODE OPERATING

DESCRIBE EMISSION POINT VENT FROM FABRIC FILTER

EMISSION POINT HEIGHT ABOVE GROUND LEVEL 40 feet

EMISSION POINT HEIGHT RELATIVE TO OBSERVER 40 feet

DISTANCE TO EMISSION POINT 300 feet

DIRECTION TO EMISSION POINT West of source

DESCRIBE EMISSIONS Continuous Light Blown plume

COLOR OF EMISSIONS Light Brown

CONTINUOUS ☑ FUGITIVE ☐
INTERMITTENT ☐

WATER VAPOR PRESENT NO ☑ YES ☐

IF YES, IS PLUME ATTACHED ☐ DETACHED ☐

AT WHAT POINT WAS OPACITY DETERMINED

DESCRIBE BACKGROUND Trees in foilage

COLOR OF BACKGROUND

SKY CONDITIONS Cloudy

WIND SPEED 13 mph

WIND DIRECTION South

AMBIENT TEMPERATURE 73°F

RELATIVE HUMIDITY 35%

COMMENTS

START TIME 1:11 pm

STOP TIME 1:26 pm

	0	15	30	45		0	15	30	45
1	5	5	5	5	31				
2	5	5	5	5	32				
3	5	5	0	5	33				
4	5	10	5	5	34				
5	10	10	5	5	35				
6	0	5	5	5	36				
7	0	10	5	5	37				
8	5	10	10	5	38				
9	10	5	0	0	39				
10	5	10	10	5	40				
11	5	5	5	5	41				
12	0	0	5	5	42				
13	10	10	5	5	43				
14	5	0	5	0	44				
15	5	5	5	5	45				
16					46				
17					47				
18					48				
19					49				
20					50				
21					51				
22					52				
23					53				
24					54				
25					55				
26					56				
27					57				
28					58				
29					59				
30					60				

AVERAGE OPACITY 5.2 %

NUMBER OF READINGS ABOVE 10 % WERE 0

RANGE OF OPACITY READINGS FROM 0 TO 10

SOURCE LAYOUT SKETCH

DRAW NORTH ARROW

X EMISSION PT.

O bserver

☼ sun

OBSERVER'S SIGNATURE Inspector

DATE 4/18/81

I HAVE RECEIVED A COPY OF THESE OPACITY OBSERVATIONS.

SIGNATURE Plant Manager

VERIFIED BY

TITLE PLANT MANAGER

DATE 4/18/81

PHOTOGRAPHS

STACK TEST RESULTS